AN ASSESSMENT OF THE PRACTICAL AND ENVIROMENTAL IMPLICATIONS OF MECHANICAL HARVESTING OF AQUATIC VEGETATION IN SOUTHERN CHEMUNG LAKE

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PREFACE

The experimental macrophyte harvesting programme in Southern Chemung Lake was initiated in 1973 as part of the Kawartha Lakes Water Management Study. This overall study was concerned with changes in water quality and identification of problems peculiar to this waterway. [The Kawartha Lakes Water Management Study - Water Quality Assessment (1972-1976) Ministry of the Environment report, November 1976, 185p.]. The purpose of this programme was to define the environmental consequences of large scale vegetation removal on the aquatic ecosystem.

The proliferation of aquatic macrophytes in many shallow Ontario lakes has become a major detriment to recreational usage, particularly since the invasion of Eurasian watermilfoil, Myriophyllum spicatum L. To date control of nuisance vegetation is largely achieved by chemical means. Harvesting was thought to offer a viable alternative which would have less drastic effects on the aquatic environment.

This report outlines the impact of extensive mechanical vegetation removal on the phytoplankton, zooplankton, macrophyte and fish populations and water quality on southern Chemung Lake, Ontario. This lake was selected as the study area because it supports prolific growths of aquatic plants and because it is conveniently divided by a causeway, providing ideal experimental and control areas. Supervision of the harvesting programme and the related sampling was carried out by staff of the Water Resources Branch, Ministry of the Environment. Changes in the fish populations were monitored by staff of the Fishery Unit, Lindsay District, Ministry of Natural Resources.

SUMMARY AND CONCLUSIONS

1) Following two years of background studies, experimental harvesting of aquatic vegetation was initiated in southern Chemung Lake in 1973. Between 1973 and 1976, 1150, 1940, 3020 and 4750 metric tonnes of vegetation were removed from areas of 656, 646, 734 and 883 acres, respectively. Seasonal average productivity rates for the Aquamarine machines were fairly consistent ranging between 0.37 and 0.40 acres cut per hour. The highest productivity rate of 0.43 acres/hour was obtained for a large experimental machine.

2) Annual phosphorus loadings to southern Chemung Lake were monitored in 1975 and compared to the quantity of phosphorus removed from the lake via the harvesting programme. Overland drainage and precipitation were the major contributors of phosphorus to the lake, accounting for 83% of the annual loading, while artificial inputs contributed 17%. Harvesting operations in 1975 removed 3.0×10^6 kg of plant material containing 560 kg of P. This value is equivalent to 47% of the gross annual loading and 92% of the net P retained in the lake.

3) Ambient organic nitrogen values were high while nitrate nitrogen levels showed mid-summer depletions characteristic of productive environments. Seasonal mean values for phosphorus showed a progressive increase from northern to southern Chemung both prior to and following commencement of harvesting operations. The high N/P ratios suggest that phosphorus may be the key factor controlling production in the lake and therefore continuous P removal via harvesting represents a potential means of reducing productivity. Although nutrient budget data for 1975 indicate that the equivalent of 47% of the gross and 92% of the net annual P loading to the lake was removed via harvesting, significant reductions in ambient P concentrations were not apparent during the study period. Since most aquatic plants obtain their phosphorus both from the water and the sediment, undoubtedly harvesting would have to be continued over an extended period of time before significant reductions in ambient P concentrations can be achieved.

4) The specie composition of the phytoplankton of Chemung Lake remained similar throughout the study period, with general seasonal trends typical of mesotrophic lakes. Bacillariophyceae and Chrysophyceae were dominant during the summer months. Increases in algal biomass were not observed following commencement of the harvesting programme. A maximum biomass of 4700 a.s.u./ml was obtained at the shallow weeded station in southern Chemung in the preharvest period followed by a gradual decline to 1700 a.s.u./ml by 1976.

5) Zooplankton community structure in Chemung Lake was dominated by cladocerans and cyclopoid copepods, with few calanoid copepods. Several species characteristic of shallow, warm, eutrophic lakes were present. The maximum population levels ranged as high as 85 individuals/cm^2, with yearly means ranging between 1.7 and 34.7 individuals/cm^2. Harvesting did not appear to have significantly altered the zooplankton community.

6) Macrophytes were extremely prolific in southern Chemung Lake covering an area of some 430 ha or about 50% of the lake surface. Over 20 plant species were identified in the lake and of these Eurasian watermilfoil, Myriophyllum spicatum L., Northern Watermilfoil, Myriophyllum exalbescens Fernald., and tapegrass, Vallisneria americana Michx. were the most common. During the study there was a pronounced increase in Eurasian watermilfoil with concurrent reductions in the remaining common species. This increase was considered to be unrelated to harvester activity since similar trends were apparent in other nearby lakes. Peak plant biomass values were relatively consistent throughout the study period (300 to 400 g dry wt. per m^2) although higher spring values during the latter years reflect the increase in Eurasian watermilfoil, which exhibits an early growth phase. Plant tissue concentrations of N and P were well above critical levels reported in the literature, indicating that plant growth was not restricted by nutrient availability. This suggests that while increases in ambient levels would not increase biomass production, large reductions are required before nutrients become a limiting factor for plant growth.

7. Changes in plant densities and rates of regrowth following harvesting of experimental plots indicated that multiple harvests were most

effective in reducing stem numbers and stem heights. Single harvests resulted in slight increases in stem heights although these changes were minor compared to increases of over 200% in unharvested plots.

8) Numerically, pumpkinseeds dominated trapnet catches in Chemung Lake, followed by yellow perch and walleye. With the exception of yellow perch, population estimates remained consistent over the duration of the study period. Yellow perch catches declined significantly although reductions in the populations both in southern Chemung and the northern control sector would seemingly exonerate harvester activity as a cause. Walleye harvest remained consistent in the southern sector throughout the study period but declined slightly in the northern sector. Angler effort peaked in 1972 followed by a gradual decline over the remaining years. The direct loss of fish which are entrapped in the vegetation and removed during the harvesting process was equivalent to 8.9 kg of fish per hectare harvested.

9) During the summer of 1975, personal interviews were conducted among 438 residents of southern Chemung. Local opinion of the harvesting program varied considerably and seemed largely influenced by the location of the respondents home in relation to areas harvested. Forty eight percent felt that harvesting benefited the lake, 23% felt it made no difference, 19% felt that harvesting was detrimental and the remainder had no definite opinion. A surprising 85% indicated that harvesting should be continued, with 10% opposed and 5% undecided. Fifty one percent indicated that they would be prepared to contribute funds for the harvesting program.

RECOMMENDATION

Harvesting of aquatic vegetation appears to be a viable control methodology which had no detrimental effects on the aquatic ecosystem. However, the low productivity rates and high capital costs of existent machinery would appear to limit its usefulness to larger scale projects. Considerable effort is still needed to improve the productivity of the equipment and to develop commercial uses for the harvested plant material to offset the high costs of this technique.

CHAPTER 1

THE HARVESTING OPERATION (1973-1976)

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INTRODUCTION

In the Kawartha Lakes, the presence of extensive areas of shallow waters comprised largely of flooded land, combined with an abundant nutrient supply has resulted in a tremendous proliferation of macrophytes. This production of aquatic vegetation has become a major detriment to recreational usage, particularly for activities such as swimming and boating. At the present time control of nuisance aquatic vegetation in Ontario is largely achieved on a private basis by local residents and resort operators through chemical means. Large scale use of chemicals, however, presents several drawbacks, particularly potential depletion of oxygen levels and subsequent algal blooms following decay of the plant material. As an alternate method, mechanical harvesting of nuisance vegetation is generally believed to represent a sound management approach (Hasler 1969) since large quantities of plant material are removed from the waterway eliminating the hazards of oxygen depletion and nutrients (i.e. phosphorus) contained in the plant biomass are removed from circulation within the water body. Furthermore, since this technique removes only a portion of the plants, its impact on the food chain is undoubtedly less drastic than chemical control measures. This latter factor is of prime importance in the Kawartha Lakes where the impact of a control program on the fisheries is a major consideration.

In 1973, following two years of preliminary studies, the Ministry of the Environment initiated an experimental harvesting program in Southern Chemung Lake for the purpose of assessing the effects of large scale vegetation removal on water quality, phytoplankton biomass, macrophyte dynamics and the fisheries. In addition, efforts were made to evaluate the practical aspects of equipment performance including harvesting rates and general efficiency of the mechanical systems employed.

Since harvesting generates vast quantities of plant material, the Ministry of the Environment is also funding on-going research designed to investigate practical methods of recycling the plant biomass into usable products such as livestock feeds and soil additives. Development of commercial products would be an effective method of offsetting the high costs of harvesting programs.

Contracts for the harvesting were awarded annually to private companies via a tendering process. Harvesting was generally commenced in June and terminated in October. In 1973, the harvesting program was delayed until early August due to difficulties in locating a contractor with suitable equipment. In 1976, the program included harvesting in Northern Chemung and Buckhorn Lake. Data on harvesting rates and acreages cut from these additional areas are provided in this chapter for comparative purposes. With the exception of the plant material required for research purposes, the harvested vegetation was transported to nearby farms for disposal. Generally, the vegetation was stockpiled over the summer months and applied to the fields as a soil conditioner in the fall season with manure spreaders.

DESCRIPTION OF THE HARVESTING EQUIPMENT

The harvesting operation consisted of four separate stages: (1) cutting and collection of plant material, (2) transfer to a shuttle barge for transport to shore, (3) transfer from shuttle barge, via a shore conveyor, to a truck, and (4) transport to a suitable disposal site. Plant cutting and removal was accomplished with the Aquamarine Series 650 Weed Harvester. The harvester is constructed on a barge 24 feet long, 8 feet wide and 2 feet deep. A gas-driven 35 hp power plant mounted on the barge drives 3 hydraulic pumps that in turn power the cutting and propulsion systems. Propelled by 2 side-mounted, reversible, variable speed paddle wheels, the harvester is capable of cutting a swath 8 feet wide. Reciprocating cutting bars (2 vertical 5 foot bars and 1 horizontal 8 foot cutting bar) mounted on a porous elevating conveyor are adjustable to a maximum 5 foot cutting depth. The harvested material is accumulated in the hold and unloaded from the rear by a continuous conveyor mesh. The Aquamarine Transporter barge is identical to the harvester except for the cutting table and can be linked with both the harvester and shore conveyor. The Aquamarine Shore Conveyor is an elevating conveying system for transporting the harvesting material into a dump truck. During the course of the study several different types of shuttle barges and shoreline unloading systems were used by the different contractors. (Table 1). Conventional outboard powered shuttle barges were used to replace the Aquamarine Transporter and shore transfer was accomplished by vertical lift from barge to truck using a tractor-mounted back hoe with a clam.

In 1976 a large experimental harvester was purchased by the contractor and modified locally. The machine measured 70 feet by 16 feet, with 2 to 3 times the holding capacity of the Aquamarine harvester. A 16 foot horizontal reciprocating cutting blade mounted on a front conveyor table was adjustable to a 6 foot cutting depth. Propulsion was provided by a motor-driven airplane propeller, mounted at the rear, with a 180 degree turning radius for directional control. Off-loading was accomplished by reversing the continuous live bed system, raising the front cutting table until it pivoted into place, flush with the hold, and dumping the harvested material into an enlarged high-capacity shoreline elevating system for direct transfer into trucks.

RESULTS

Extent of the Harvesting Program. The monthly and annual numbers of acres harvested are summarized in Table 2. In 1973, harvesting operations were commenced in early August with an Aquamarine harvesting trio. During September, record-breaking warm weather accelerated production of gases in the lake sediments and caused uprooting of aquatic vegetation. The material formed large floating mats which clogged the shorelines and totally impeded boat access to the deeper waters. The harvester was diverted from routine cutting to collection of the floating vegetation. Since the collection of this material could be accomplished far more rapidly than routine harvesting, the resultant acreage equivalent for September, 1973 was extremely high. In 1974 operations commenced on June 17 using a single Aquamarine harvester with the subsequent addition of a second rented machine towards the end of August. A single harvester was used from June 17 to August 4, 1975 at which time a second machine was employed by the contractor. In 1976 two Aquamarine harvesters commenced operations on June 4th. A third large experimental harvester was added on August 9, 1976.

Harvesting operations between 1973 and 1975 (inclusive) were restricted to Southern Chemung Lake as part of the experimental program. Efforts were directed towards clear-cutting of extensive weed beds to magnify any environmental effects which could result from the harvesting program. Cutting along shoreline sections was confined to the areas where dense weed growth precluded boat access to the deeper portions of the lake. A second cut was provided only in areas where rapid regrowth was observed.

TABLE 1. Harvesting equipment used in the Kawartha Lakes

	Type of Harvester	Type of Transporter	Type of Shore Conveyor
1973	1 Aquamarine Harvester (8' cut)	1 Aquamarine Transporter	1 Aquamarine shore conveyor
1974	2 Aquamarine Harvesters (8' cut)	2 conventional outboard powered barges	1 tractor mounted back hoe with clam
1975	2 Aquamarine Harvesters (8' cut)	2 conventional outboard powered barges	1 tractor mounted back hoe with clam
1976	2 Aquamarine Harvesters (8' cut)	2 conventional outboard powered barges 1 Aquamarine Transporter	1 tractor mounted back hoe with clam 1 Aquamarine shore conveyor
	1 Experimental Harvester (16' cut)	self transporting	enlarged, high capacity, continuous conveyor

TABLE 2. Extent of harvesting operations in the Kawartha Lakes.

Year	Acreages Cut					
	June	July	Aug.	Sept.	Oct.	Total
1973	-	-	94	464	98	656
1974	59	124	130	114	174	646
1975	27	120	147	199	219	734
1976	115	156	250	224	138	883

Due to the presence of submersed logs and stumps, several portions of the lake, particularly in the extreme Southern end, were excluded from the harvesting. The extent and location of the areas cut between 1973 and 1975 are illustrated in figures 1, 2 and 3.

In 1976, the harvesting was extended into Northern Chemung and Buckhorn Lakes as recommended in the Report to the C.O.R.T.S. Agreement Board from the Sub-Committee on Aquatic Plant Problems (February 1976). In compliance with the recommendations made, major efforts were directed towards opening up channels for fishing and access to the main navigation channels. Also, several large areas were clear-cut for recreational purposes. The locations of the areas harvested in Chemung and Buckhorn Lakes in 1976 are illustrated in figures 4, 5, and 6. The total acreages cut in each lake during 1976 are tabulated below:

Southern Chemung Lake	-	234 acres
Northern Chemung Lake	-	128 acres
Buckhorn Lake	-	521 acres
total		883

Harvesting Efficiency. Information on total harvester days spent on the lake(s), total hours worked, actual cutting time, down time and harvester productivity between 1973 and 1976 is provided in Table 3. The total hours worked represent the time spent on the harvesting program as recorded on daily log sheets and down time is equivalent to the difference between the total time and actual cutting time. Harvester productivity is expressed as the seasonal average acreage cut per hour of actual cutting time.

The down time is primarily a result of various mechanical failures although time lost due to inclement weather conditions or moving of equipment to a new location during regular shift time is also included. The lowest percentage of down time (12%) was obtained in 1973, undoubtedly due to the fact that collection of the floating material reduced the potential for mechanical failure, i.e. running into underwater obstacles. The down time during the successive years was remarkably similar, ranging between 26 and 30% of the total time. However, in 1976, while similar values (24.9 and 27.3%) were recorded for the two Aquamarine harvesters, the large experimental machine was non-operational 41.7% of the time,

TABLE 3. Harvesting efficiency in the Kawartha Lakes.

	1973	1974	1975	1976
Total harvester-days on lake	74	200	220	366
Average acreage cut per harvester-day	4.5	3.2	3.3	2.4
Total hours worked	1125	2365	2663	3327
Total hours active cutting	988	1744	1855	2356
Down time (%)	12	26	30	29
Average acres cut/hour	0.38*	0.37	0.40	0.37
Cost/acre ($)	140	114	134	139

*excludes acreage equivalent for collection of floating vegetation.

largely as a result of mechanical difficulties. Although not entirely comparable due to the large number of variables affecting a harvesting operation, Dane County, Wisconsin, (Bruhn, Koegel and Livermore 1973) reported similar values for their non-operational time in 1972 and 1973. For the Aquamarine harvester, down time for mechanical reasons represented 6.7 and 26% of the total time, moving to a new location accounted for 11.3 and 8.8% and cessation of operations due to inclement weather resulted in a time loss of 5.0 and 6.2%.

The harvester productivity was undoubtedly influenced by a number of factors such as operator experience, wind velocity and wave action, plant density and cutting location, and distance to the unloading site. In deeper waters with dense plant growth to the surface, the cut areas were clearly visible, thus allowing the operator to reduce the amount of overlap for each successive swath. Furthermore the hazard of running into underwater obstacles was substantially reduced. On the other hand, the harvesters were filled more frequently, and additional time was spent transferring the plant material into the transporter barges. In the shallower shoreline areas the productivity was affected by temporary turbidity caused by disturbance of the sediments which impaired operator visibility and frequently resulted in extensive overlapping of swaths reducing the overall effective cutting width to an estimated four feet. Also, the forward speed was frequently curtailed by the presence of underwater obstacles and boat docks. As a result of these variables, the calculated productivity rates for different harvesting sites fluctuated widely from 0.16 to 0.84 acres/hour. A similar wide range of values (0.47 to 1.16 acres/hr.) was reported for the aquamarine harvester operated by Dane County, Wisconsin.

The overall seasonal average productivity rates for the aquamarine machines were remarkably similar (0.37 to 0.40 acres/hr.), but considerably lower than the seasonal average of 0.63 acres/hr. reported for the Dane County Operation. The highest seasonal average of 0.43 acres/hour was obtained for the large experimental harvesting machine although its overall usefulness to the program was seriously curtailed by the previously mentioned high percentage of down time.

Based on the foregoing, it is apparent that aquatic plant harvesters have not yet achieved the reliability and productivity common to modern agricultural machinery. Assuming an average working season of 120 days, 10 hour daily shifts and a 25% down time, the actual effective cutting time is about 900 hours. Based on a productivity rate of 0.37 acres/hour, a single machine can be expected to cut only about 330 acres per season.

Plant Biomass Removed. The total plant biomass removed each season was obtained by multiplying the total number of truck loads (2 harvester loads) by an average load weight. Efforts were made to weigh several truck loads from each harvesting site to provide an accurate average wet weight. The dry weight was determined from data on the water content of the major plant species collected during the routine monitoring of macrophyte dynamics in Chemung Lake (Chapter 6). Similarly, the nitrogen and phosphorus content of the harvested plants was based on data provided by the macrophyte sampling program. Table 4 summarizes information on the total plant biomass removed annually by harvesting, average metric tonnage per acre and the quantities of nitrogen and phosphorus removed.

The wet weights per harvester load for the Aquamarine machines were fairly consistent over the four year period, ranging between 1.5 and 1.8 metric tonnes. The weights for the large experimental harvester were considerably higher, averaging 5.6 metric tonnes wet weight per load.

The progressive increase in the average tonnage of vegetation removed per acre was not entirely unexpected and reflects the increase in the biomass of Eurasian watermilfoil (Myriophyllum spicatum L.) in Chemung Lake. This plant is usually well branched with numerous stems reaching the surface by mid-June, thus providing a higher tonnage per acre earlier in the season than communities of mixed plant species which mature at a later date. Furthermore, on the upper portions of the milfoil stems, the whorls of leaflets are more compact with short internodes, whereas the lower portions of the stems are frequently defoliated. As a result, the harvesters remove the bulkiest portions of the plants. The increase in the tonnage removed per acre was particularly noticeable in 1976 in North Chemung and Buckhorn lakes where the harvested areas were almost exclusively populated by the Eurasian watermilfoil. In Southern Chemung Lake the tonnes of vegetation removed per acre were calculated separately for each harvesting site from 1973 to 1975. Values ranged from a minimum of 1.1 tonnes/acre

TABLE 4. Plant biomass removed from the Kawartha Lakes via harvesting

	1973	1974	1975	1976
Number of harvester loads	636	1253	1672	2435
Total plant biomass removed (metric tonnes wet wt.)	1150	1940	3020	4750
Total plant biomass removed (metric tonnes dry wt.)	95	185	310	570
Average metric tonnes (wet weight)	1.7	3.0	4.0	5.4
Total nitrogen removed (kg)	1790	3920	5980	13650
Total phosphorus removed (kg)	182	435	564	1420

to a maximum of 9.3 tonnes/acre and were influenced by water depths, types of vegetation present and the time of the season. Similar values were reported from Dane County, Wisconsin, with a range of 1.2 to 10.2 tonnes/acre and a seasonal average of 2.9 tonnes/acre.

The plant biomass removed from Southern Chemung Lake represents an estimated 7.1% (1973), 11.3% (1974) and 18.7% (1975) of the peak plant biomass in the lake. The nitrogen removed via the harvesting program represents 7.4%, 15.5% and 21.2% of the total nitrogen tied up in the plant biomass in the lake in 1973, 1974 and 1975 respectively. Phosphorus removal was equivalent to 7.1% (1973), 15.9% (1974) and 18.9% (1975) of the estimated total plant phosphorus in the lake. The significance of the phosphorus removal to the nutrient budget of the lake is discussed in Chapter 2.

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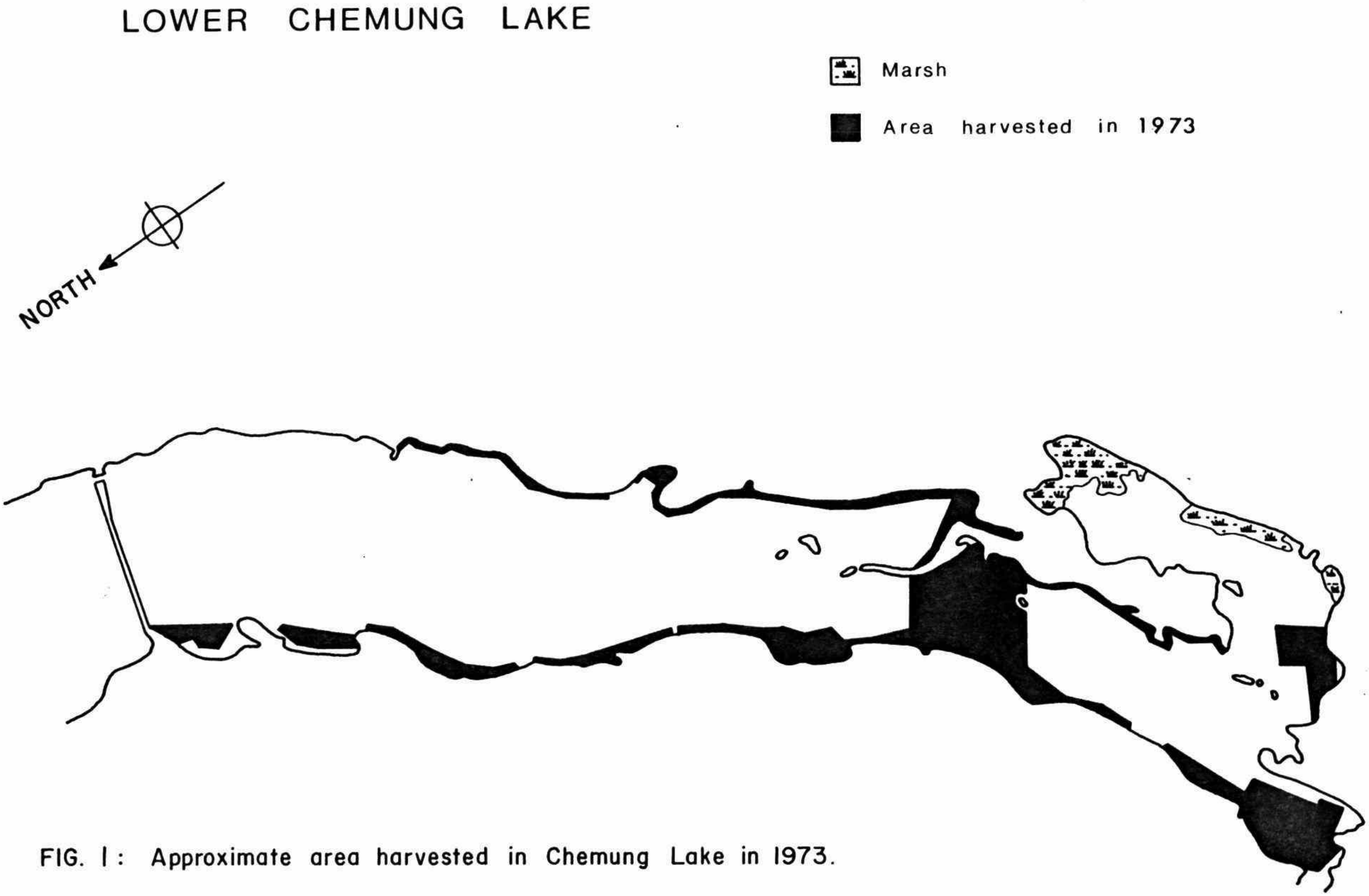


FIG. 1: Approximate area harvested in Chemung Lake in 1973.

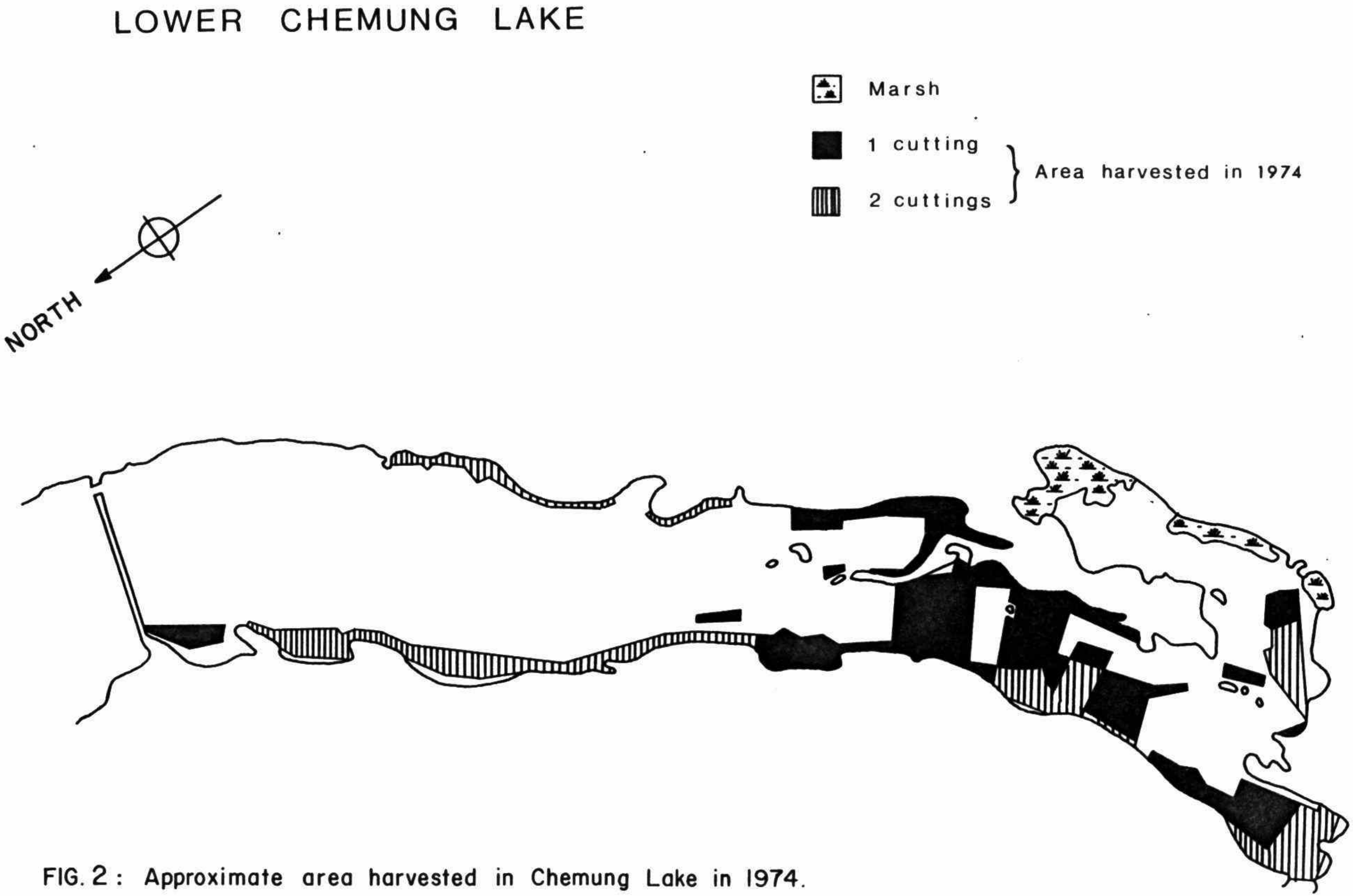


FIG. 2 : Approximate area harvested in Chemung Lake in 1974.

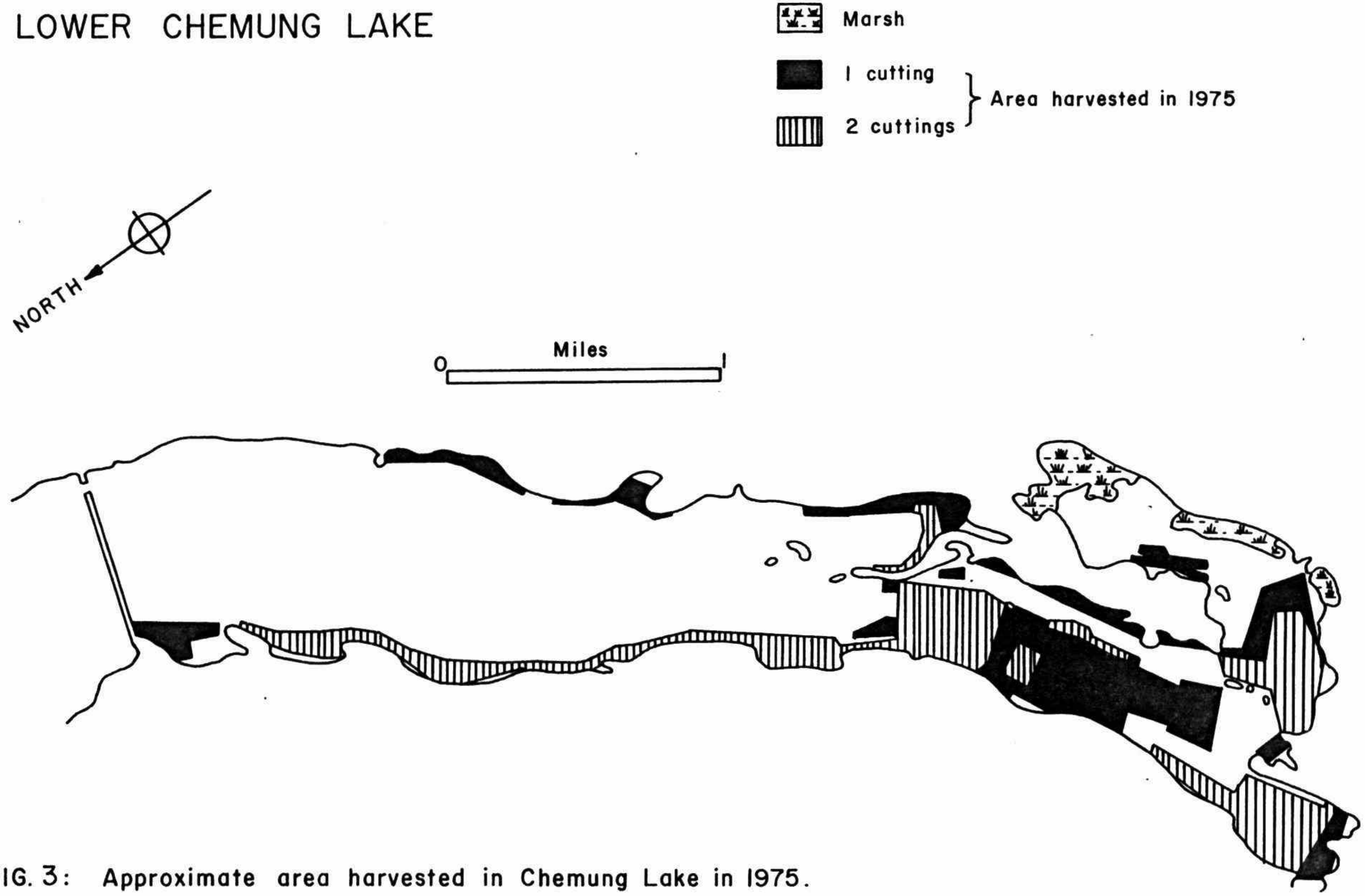


FIG. 3: Approximate area harvested in Chemung Lake in 1975.

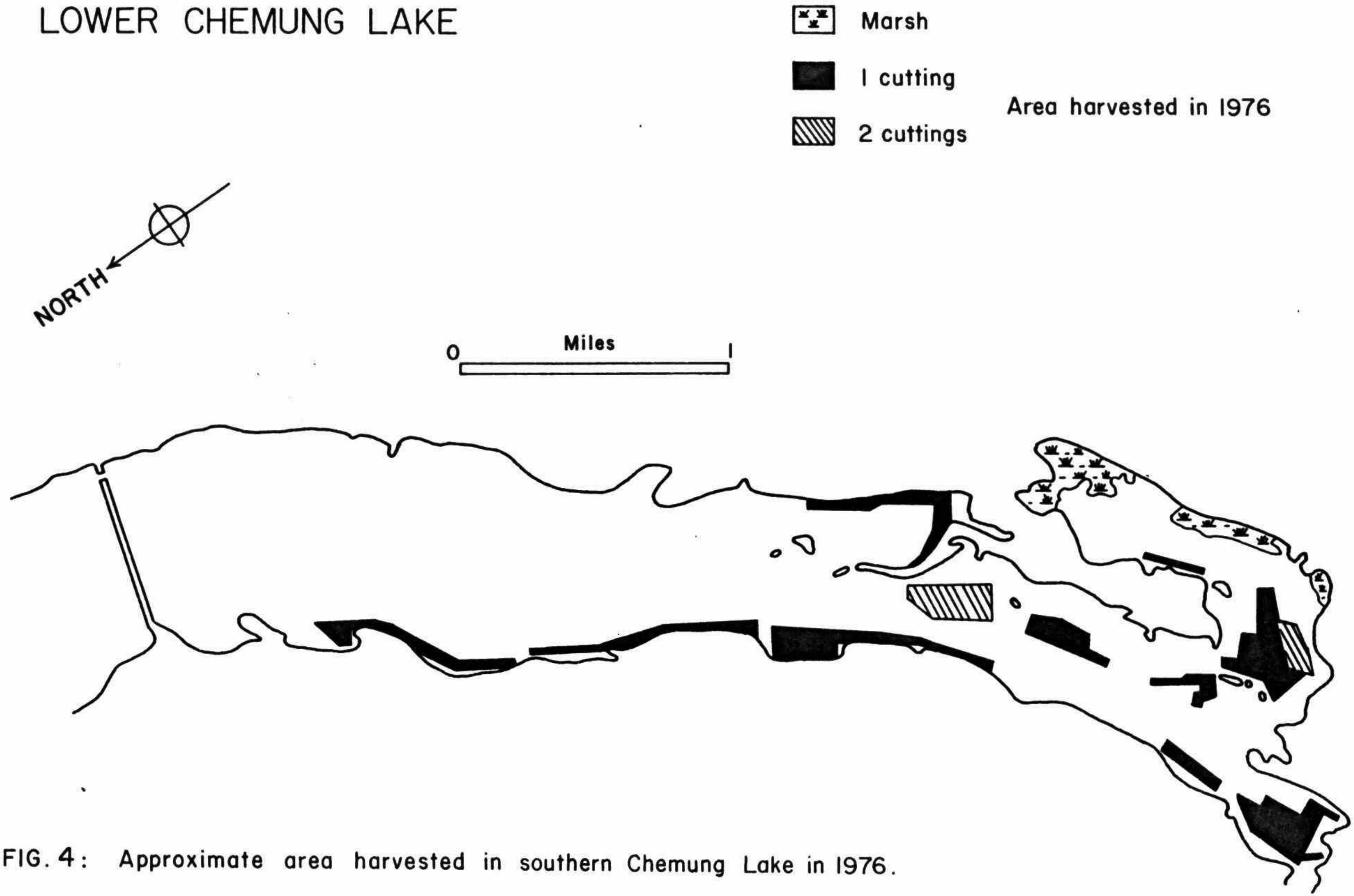


FIG. 4: Approximate area harvested in southern Chemung Lake in 1976.

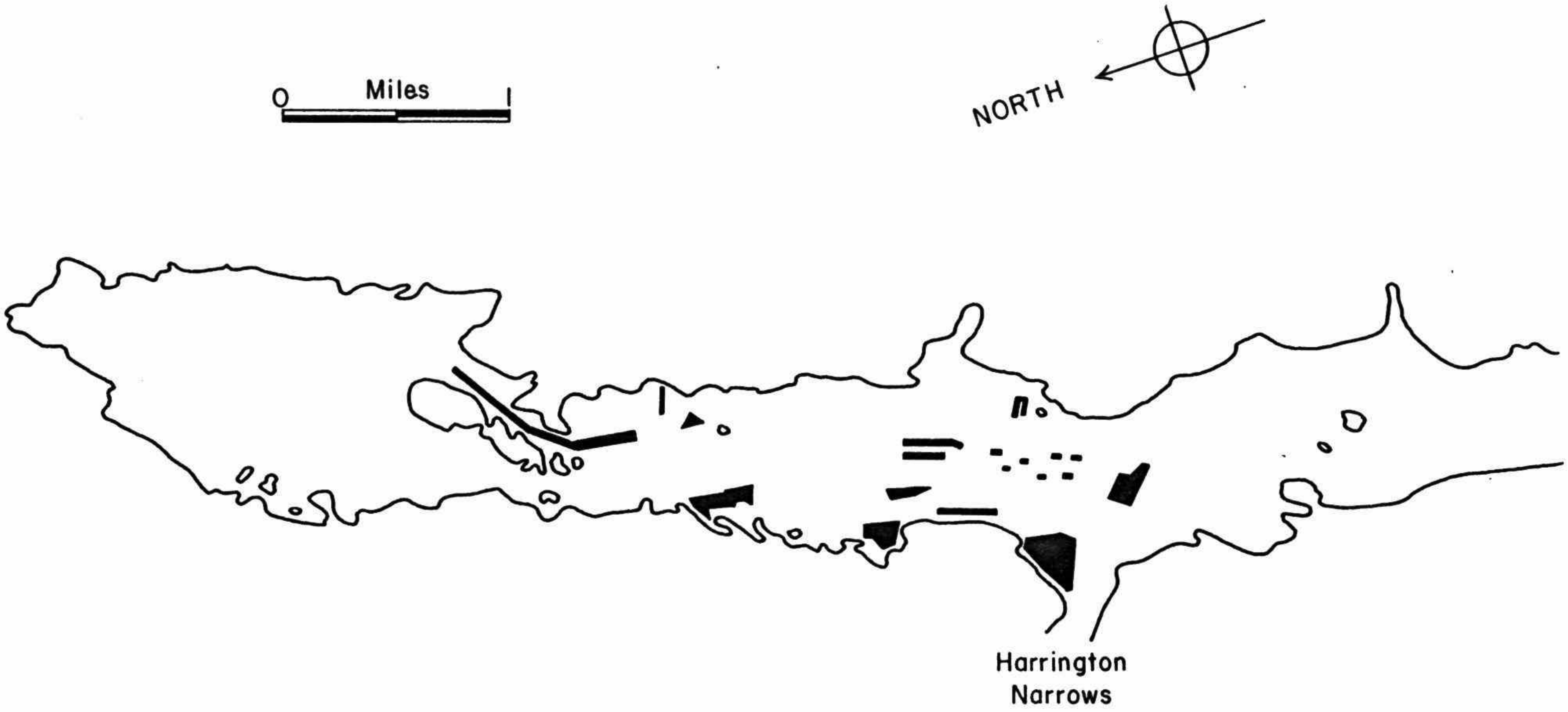
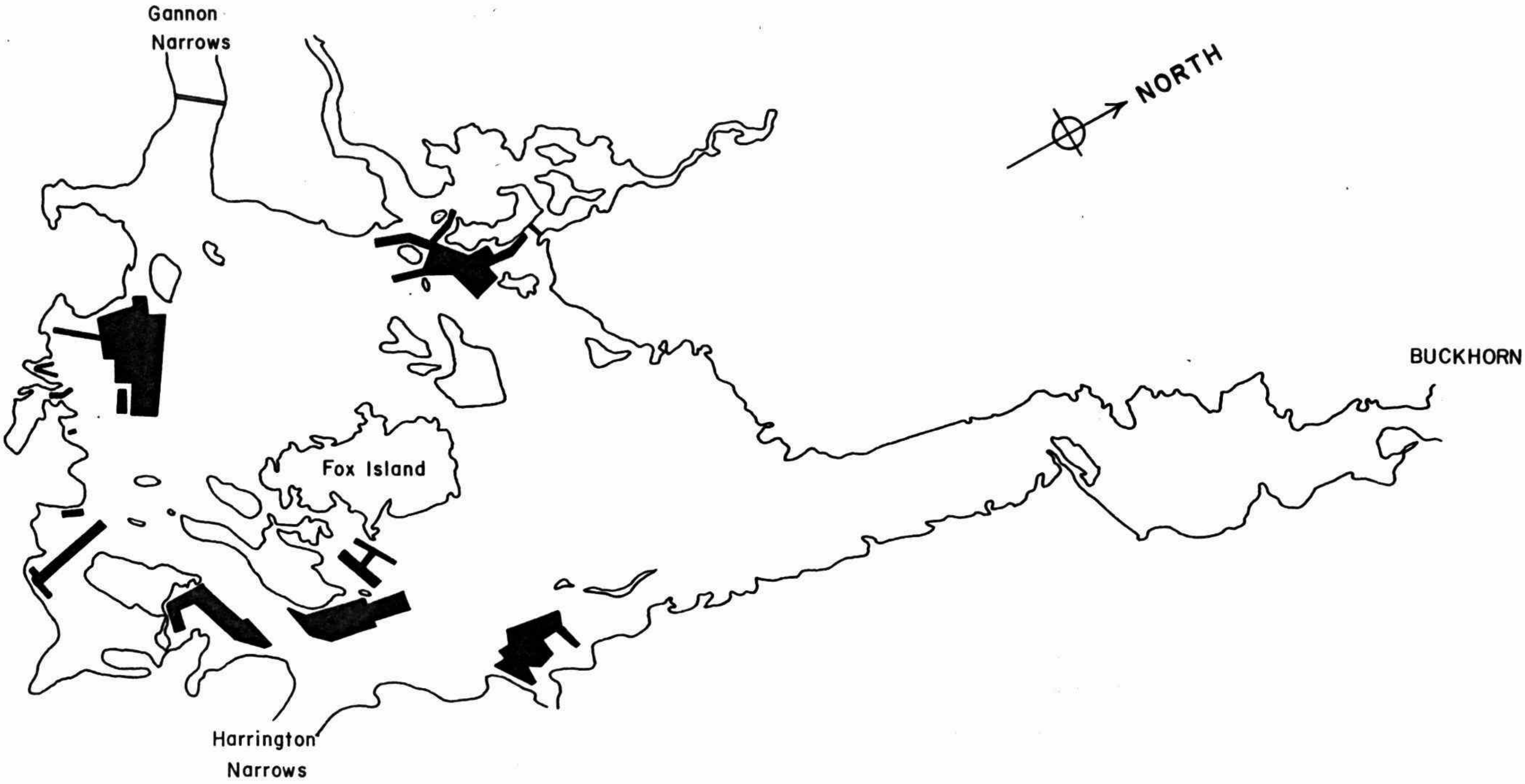


FIG. 5: Approximate area harvested in northern Chemung Lake in 1976.

FIG. 6 : Approximate area harvested in Buckhorn Lake in 1976.



CHAPTER 2

THE NUTRIENT BUDGET OF SOUTHERN CHEMUNG LAKE AND NUTRIENT REMOVAL THROUGH HARVESTING OF AQUATIC VEGETATION. (1975)

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DEFINITION OF SYMBOLS

Ev	total volume of lake water lost via evaporation
J_A	total phosphorus input from artificial sources
J_E	total phosphorus input from watershed drainage
J_{PR}	total phosphorus input from precipitation
N	number of residences
O_T	total phosphorus loss via outflow
P_r	total volume of precipitation on lake surface
Q	total lake outflow volume
R	total volume of run-off from watershed drainage
S_{net}	net total phosphorus retention in lake

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Figure 1. Daily discharge from two streams draining into lower Chemung Lake (1975).

Figure 2. Daily discharge from Jackson's Creek at Peterborough (1975).

INTRODUCTION

Large-scale mechanical harvesting of aquatic vegetation has frequently been advocated as a means of removing nutrients from lakes to alleviate the problems of eutrophication. (Livermore 1954, Hasler 1969 and Yount and Crossman 1970).

In 1975 the annual phosphorus loading to southern Chemung Lake was calculated and compared to the phosphorus removed through harvesting of aquatic vegetation and fish export. The nutrient budget was developed from inputs from three separate catchment basins which drain into the lake as well as inputs from precipitation and artificial sources. Phosphorus losses via the outflow and the net phosphorus retention were also determined.

METHODS

Precipitation Collection

A rainfall collector, consisting of a 0.25 m diameter wire mesh covered plastic funnel that emptied into a clean glass bottle, was installed on a rooftop at Trent University, Peterborough. Rain samples were collected after each precipitation event between May 2 and September 22, 1975. The total annual precipitation was determined from monthly meteorological records obtained from the Atmospheric Environment Service in Peterborough. (Table 1).

Discharge Measurements

Run-off entering lower Chemung Lake was measured for the two tributary streams, Chemung Creek (with a drainage area of 13.5 sq. km) and Lancaster Creek (12.7 sq. km). Lancaster Creek was gauged twelve times between April 17 and July 28, 1975 with an Ott current meter. Flow after June 23, 1975 was negligible. Although the Chemung Creek site was poorly suited to the collection of streamflow data, it was instrumented with a temporary water level recorder and stream discharge was measured once a week (from April 17 to October 20). A good stage discharge curve was developed to provide daily discharge information (Fig. 1).

Since the outflow via a causeway separating southern and northern Chemung Lake could not be gauged, the outflow discharge was determined

TABLE 1. Summary of precipitation at Peterborough Airport (1975)

Month	Total Precipitation (mm)
January	48.5
February	60.2
March	80.8
April 1-17	45.5
April 18-30	25.1
May	98.8
June	59.4
July	118.
August	43.2
September	53.4
October 1-20	19.5
October 21-30	1.8
November	65.0
December	69.7
Total	789

from the following equation:

$$Q = Pr + R - Ev$$

where Q = total lake outflow volume

Pr = total volume of precipitation on the lake surface

R = total volume of runoff from the watershed

Ev = total volume of lake water lost via evaporation

Chemical Analyses

Total phosphorus analyses were performed weekly for water samples taken from both the outflow and the two inlet tributaries. Nutrient analyses were also performed on rainwater samples following each rainfall event by the Ministry of the Environment's Laboratory division.

RESULTS AND DISCUSSION

Total Phosphorus Input from Precipitation (Jpr)

The phosphorus inputs from precipitation are summarized in Table 2. Inputs for the period between May 2 and September 22, 1975 were obtained by multiplying the total volume of each rainfall by the measured phosphorus concentration for each event. For the remainder of the season, an average phosphorus concentration of 0.018 mg/l was used, as suggested by Nicholls (1976) for rain and snow mixtures.

The total annual atmospheric phosphorus loading to southern Chemung Lake was 490 kg or 58 mg P/m^2. This value lies within the range outlined for other southern Ontario lakes, namely, 77 mg P/m^2 (Dillon 1974a), 74.5 mg/m^2 (Nicholls 1976) and 37 mg P/m^2 (Gomolka 1975).

Total Phosphorus Input from Watershed Drainage (J_E)

A. Gauged Tributaries

The lower Chemung Lake watershed consists of three separate catchment basins (Table 3), two of which are drained by permanent streams. Phosphorus inputs at the stream monitoring stations were calculated by multiplying volume input per sampling interval by the measured phosphorus concentrations (Tables 4, 5). Stream discharges are illustrated in Fig. 1. Total phosphorus loadings for the period between April 17 and October 20, 1975 were 29 kg P for Lancaster Creek and 48 kg P for Chemung Creek.

Data for the remainder of the year was extrapolated from information collected from a nearby stream, Jackson's Creek, as part of the Water Survey of Canada. Discharge patterns (Fig. 2) for Jackson's Creek were similar to Chemung Creek, thus justifying the use of this data. Table 6 shows that 38% of the annual discharge occurred during the time interval between April 17 to October 20. This volume of discharge resulted in a loading of 29 kg P for Lancaster Creek and 48 kg P for Chemung Creek or a total loading of 77 kg P. Assuming that the Chemung Lake streams had similar phosphorus concentrations during the remainder of the year, the total annual phosphorus loading for the Lancaster and Chemung Creek basins was calculated as 100/38 x 77 or 202 kg P. This is equivalent to 7.7 mg P/m$^2\cdot$yr^{-1} (Table 7).

TABLE 2. Total phosphorus load from precipitation to southern Chemung Lake. (lake area = 8.58×10^6 m^2).

Period	Precipitation (mm)	Measured P Concentration of Rainwater (mg/l)	Total P Load (kg)
May 2-5	16.3	0.21	29.3
May 6-16	11.4	0.73	71.6
May 17-21	3.81	0.60	19.6
May 22-June 2	69.6	0.31	185.
June 3-6	15.8	0.09	12.2
June 7-12	10.2	0.11	9.59
June 13-16	10.2	0.04	3.49
June 17-19	9.14	0.06	4.71
June 20-24	11.2	0.09	8.63
June 25-July 11	11.4	0.33	32.4
July 12-21	84.1	0.03	21.7
July 22-25	7.87	0.08	5.40
July 26-28	14.48	0.04	4.97
July 29-Aug. 11	3.56	0.19	5.80
August 12-29	39.6	0.03	10.2
Aug. 30-Sept. 19	40.5	0.01	3.48
Sept. 20-22	8.70	0.01	0.75
Sub-Total	368.		429.
Remainder of Season	421.	.018	64.9
Total	789		494

TABLE 3. Drainage Basins for Southern Chemung Lake

Drainage Basin	Drainage Area (km^2)
1. Lancaster Creek	12.7
2. Chemung Creek	13.5
3. Overland (no creeks)	32.3
Total	58.5

TABLE 4. Mean total phosphorus concentrations, total water volume, and total phosphorus load for each of 10 sampling periods between April 17 and June 23, 1975 (Lancaster Creek).

Date	Mean Total P Concentration (g/m^3)	Volume ($x\ 10^4\ m^3$)	Total P Load (kg)
April 17-24	0.027	35.4	9.6
April 25-29	0.031	12.8	4.0
April 30-May 8	0.026	12.8	3.3
May 9-12	0.038	3.6	1.4
May 13-20	0.063	3.0	1.9
May 21-26	0.099	1.7	1.7
May 27-June 2	0.108	2.9	3.2
June 3-10	0.083	2.5	2.1
June 11-16	0.081	1.2	1.0
June 17-23	0.089	1.3	1.1
June 24-Oct. 20	-	0	0
Totals		77.2	29.

TABLE 5. Mean total phosphorus concentrations, total water volume, and total P load for each of 24 sampling periods between April 17 and October 20, 1975 (Chemung Creek).

	Mean Total P Concentration (g/m^3)	Volume ($m^3 x 10^4$)	Total P Load (kg)
April 17-24	0.016	30.1	4.8
April 25-29	0.016	10.4	1.7
April 30-May 8	0.023	13.8	3.2
May 9-12	0.027	4.3	1.2
May 13-20	0.037	5.7	2.1
May 21-26	0.051	3.3	1.7
May 27-29	0.055	2.5	1.4
May 30-June 5	0.048	4.4	2.1
June 6-13	0.035	4.9	1.7
June 14-19	0.047	3.7	1.7
June 20-26	0.050	2.4	1.2
June 27-July 3	0.069	0.6	0.4
July 4-10	0.064	1.4	0.9
July 11-17	0.036	1.2	0.4
July 18-24	0.130	9.7	12.6
July 25-Aug. 5	0.070	1.9	1.3
Aug. 6-23	0.060	0.1	0.0
Aug. 24-28	0.031	1.4	0.4
Aug. 29-Sept. 5	0.042	7.4	3.1
Sept. 6-12	0.028	3.4	1.0
Sept. 13-22	0.027	7.5	2.0
Sept. 23-29	0.026	4.6	1.2
Sept. 30-Oct. 6	0.021	2.9	0.6
Oct. 7-20	0.021	6.5	1.4
Total		134.	48.

TABLE 6. Annual discharge in Jackson's Creek at Peterborough in 1975. (corresponding to the monitored and unmonitored time periods for Chemung Lake streams)

Month	Discharge (mean cfs)	Volume (m^3/monthx10^6)	Total Volume (x 10^6 m^3)	% of annual discharge
January	30.4	81.4		
Feb.	30.1	75.4	579	51.5
March	123.	329.		
April 1-16	67.6	93.5		
April 17-30	196.	220.		
May	31.1	83.3		
June	16.0	41.5		
July	10.1	27.1	428	38.0
August	4.50	12.1		
Sept.	10.7	27.7		
Oct. 1-20	9.39	16.2		
Oct. 21-31	9.19	7.94		
Nov.	16.7	43.3	118	10.5
Dec.	25.1	67.2		
Total		1125		

TABLE 7. Estimated discharge and total phosphorus load for the unmonitored time period for Chemung and Lancaster Creeks, 1975.

	Lancaster Creek	Chemung Creek
Measured discharge (April 17-Oct. 20) ($m^3 \times 10^5$)	7.73	13.4
% of flow during unmonitored period	62	62
Estimated discharge for unmonitored period ($m^3 \times 10^5$)	12.5	21.6
Estimated annual discharge ($m^3 \times 10^5$)	20.2	35.0
Total P load for monitored period (kg)	29	48
Total P load for unmonitored period (kg)	47	78
Total annual P load (kg)	76	126
Export coefficient ($mg/m^2/yr$)	6.0	9.3

B. Ungauged Watershed

To determine the total P load to lower Chemung Lake from the ungauged catchment basin, the following assumptions were made:

1. The total water equivalent volume of the winter precipitation (December 1 to April 30) falling on the basin was assumed to run off (Table 8) since the ground was either frozen or completely saturated. A weighted mean concentration of 0.023 mg P/l (as determined from measured stream inflows during the April 17 to April 30 period) was used and the resultant phosphorus load for this 4 month period was calculated as 245 kg.

2. The phosphorus load for the remainder of the year was obtained by multiplying the total precipitation for that period (Table 8) by an average ground water concentration of 0.017 mg/l (Brandes - 1974). Information collected from the gauged basins, however, indicated that only 19.4% of the precipitation on those areas reached the lake (Table 8). Therefore a similar retention factor was applied to the ungauged basin to provide a calculated phosphorus load of 49 kg. The combined annual phosphorus load from the ungauged watershed was therefore estimated as 294 kg or 9.1 mg/m^2/year.

Artificial Input (J_A)

The potential phosphorus loading to southern Chemung Lake from artificial sources (cottages and residences) was calculated from the following equation:

J_A = 0.80 kg/capita year x number of residences (N) x average number of capita years/residence.

The value of 0.8 kg P per capita year was derived by Dillon (1974b) following a review of 13 studies conducted in North America and Europe. The occupancy rate was determined from a field survey which included 60% of the residences 1 to 3 lots back from the lake perimeter.

The number of residences (both seasonal and permanent) surveyed, occupancy rates and resultant potential phosphorus loadings are summarized

TABLE 8. Total precipitation falling on the gauged and ungauged catchment basins on lower Chemung Lake and measured runoff.

Precipitation on gauged area for monitored period (April 17 - Oct 20) (m^3)	10.9×10^6
Measured runoff from gauged area for monitored period (April 17 - Oct 20) (m^3)	2.12×10^6
% runoff from gauged area	19.4
Precipitation on ungauged area from Dec. 1 to April 30 (m^3)	10.6×10^6
Precipitation on ungauged area for remainder of year (m^3)	14.8×10^6

TABLE 9. Potential artificial phosphorus loading to southern Chemung Lake based on a field survey of 60% of the residences. (Per capita loading of 0.8 kg based on Dillon 1974b)

Number of Residences	capita years/year	Potential P load (kg)
188 cottages	0.85	128
250 permanent homes	2.98	596
	Total	724

in Table 9. Since the phosphorus loading of 724 kg (Table 9) represents the loading from only 60% of the residences on the lake, an additional 40% was added bringing the total potential artificial load to 1010 kg P.

Studies conducted by Brandes (1972, 1974) on conventional septic tank disposal systems on Chemung Lake indicated that phosphorus retention in the tile fields was relatively high (about 78% on Chemung sand and higher on clay-silt soil mixtures). Since the residences surrounding the lake are located on a variety of soil types ranging from low lying swampy areas to clay-silt soils, it was felt that an average phosphorus retention factor of 80% could be applied to the artificial loading thus providing an estimated loading figure of 200 kg phosphorus per year.

Total Phosphorus loss via the Outflow (O_T)

As previously indicated, the outflow from southern Chemung, via a causeway, could not be gauged. As a result, it was necessary to calculate the outflow volume from the following equation:

$$Q = Pr + R - Ev$$

The total annual waterload to the lake from precipitation and runoff was calculated as 30.7×10^6 m^3 (Table 10). Assuming a mean annual lake evaporation of 25 inches or 0.635 m (Bruce and Weisman 1966), the loss through evaporation was equal to $5.45 \times 10^6 m^3$, resulting in a total outflow volume of 25.2×10^6 m^3.

The phosphorus loss via the outflow (O_T) was calculated as:

$$O_T = Q \times P \text{ concentration in outflow}$$

Since the mean phosphorus concentration in the outflowing water was 0.023 mg/l, the total phosphorus loss was equal to 580 kg.

Net Phosphorus Retention in the Lake (S_{net})

The net annual phosphorus retention (S_{net}) was calculated as the difference between the various inputs and the phosphorus loss via the outflow. A final net retention value of 610 kg or approximately one half of the total

TABLE 10. Outflow volume (Q) for southern Chemung Lake

Volume of Precipitation on lake (Pr)		6.77×10^6 (m^3)
Runoff (R) from ungauged basin		
a) Dec. 1 - April 30 (100%)		10.6×10^6 (m^3)
b) Remainder of year (19.4%)		2.88×10^6 (m^3)
Runoff (R) from gauged basins		
a) Dec. 1 - April 30 (100%)		7.98×10^6 (m^3)
b) Remainder of year (19.4%)		2.46×10^6 (m^3)
	Sub Total	30.7×10^6 (m^3)
Evaporation (Ev)		5.45×10^6 (m^3)
	Total	25.2×10^6 (m^3)

phosphorus input to the lake was derived from the following equation:

$$S_{net} = J_{PR} + J_E + J_A - O_T$$

$$S_{net} = 490 \text{ kg} + 500 \text{ kg} + 200 \text{ kg} - 580 \text{ kg}$$

Implications of Phosphorus Removal via Harvesting of Aquatic Vegetation and Fish Export

The annual phosphorus loading from land drainage, precipitation, artificial sources and phosphorus losses via the outflow, vegetation removal and fish export are summarized in Table 11.

Harvesting operations in 1975 resulted in the removal of 3.0×10^6 kg of plant material (wet weight) containing a total of 560 kg of phosphorus. When considered in context of the overall nutrient budget, this value is equivalent to 47% of the gross annual P load and 92% of the net P retained in the lake and represents a significant source of phosphorus removal. In a study conducted in Lake Sallie, Minnesota (Peterson et al. 1974) aquatic plant harvesting operations resulted in the removal of only 1.37% of the total phosphorus inputs to the lake leading the authors to conclude that weed harvesting was not effective as a method of reducing nutrient supplies in lakes receiving cultural enrichment. When data for the two lakes are compared, the reasons for the obvious discrepancy in conclusions are readily apparent. Harvesting operations in Lake Sallie removed only 4.28×10^5 kg of plant material or less than one sixth of the quantity removed from southern Chemung Lake. Similarly, Lake Sallie has a 60 year history of nutrient enrichment by wastewater effluent from the city of Detroit lakes and received an annual phosphorus input of 7285 kg. By comparison, the annual phosphorus loading to Chemung Lake is only 1190 kg. Furthermore, whereas in lower Chemung Lake (mean depth 1.8 m) the aquatic plants cover a total area of 435 ha, in Lake Sallie (mean depth 5.6 m) the macrophytes occupy only 158 ha of the lake surface. From the foregoing it is readily apparent that harvesting of aquatic vegetation cannot be expected to contribute significantly to nutrient reduction in Lake Sallie.

Phosphorus removal from Chemung Lake via fish export was of minor

TABLE 11. Summary of phosphorus inputs and phosphorus losses for southern Chemung Lake

	P (kg)	%
INPUTS		
land drainage	500	42
precipitation	490	41
artificial	200	17
Total	1190	
OUTPUTS		
outflow	580	49
RETENTION		
S_{net}	610	51
P REMOVAL		
plant harvesting	560	
fish export	30	

significance when compared to reductions through plant harvesting. The annual harvest for the four major game fish species was 5.2 kg/ha or 4460 kg of wet weight. Removal of coarse fish trapped in the harvested vegetation was equivalent to 1 g/kg of vegetation or 3020 kg. Bull and MacKay (1976) estimated that the phosphorus content of fish ranged between 0.3 and 0.5% of the wet weight. Assuming an average P content of 0.4%, fish export resulted in the removal of only 30 kg of phosphorus from lower Chemung Lake.

Although the removal of phosphorus via fish export and plant harvesting has not yet had an apparent effect on ambient P concentrations in the lake, repetitive harvesting could ultimately have a significant impact on the lake's phosphorus budget. Hutchison (1957) indicated that phosphorus may limit production in lakes where the N/P ratio (total Kjeldahl plus nitrate to Total P) exceeds 20:1 (by moles) or 9:1 (by weight). Since N/P ratios in Chemung Lake are high, phosphorus removal probably represents the best method for reducing production within the lake.

ACKNOWLEDGEMENT

Appreciation is extended to Mr. Jim Eddie, Water Resources Branch, Ministry of the Environment, for supplying and installing the water level recorders.

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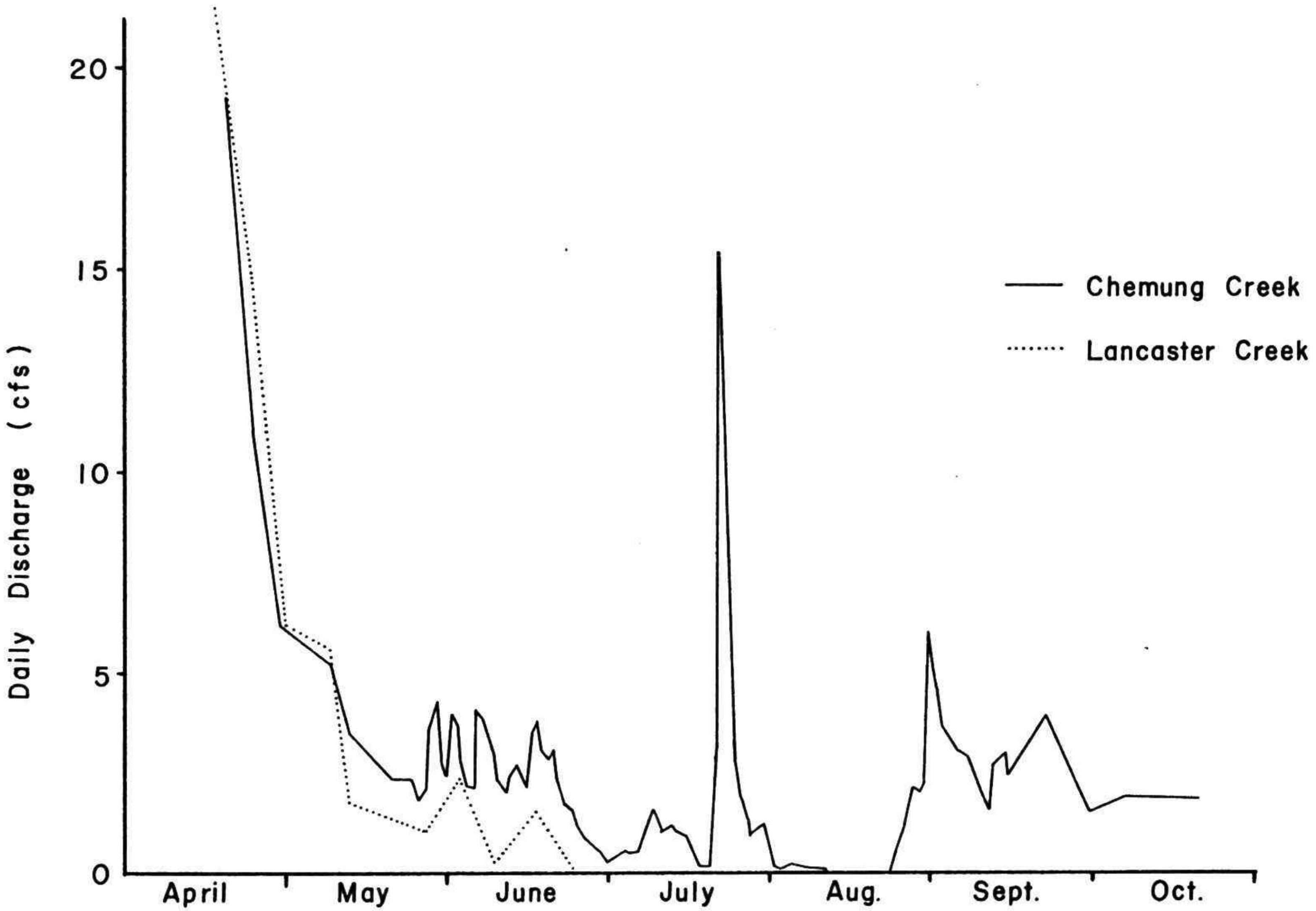

FIG. I Daily discharge in cubic feet per second from two streams draining into lower Chemung Lake in 1975.

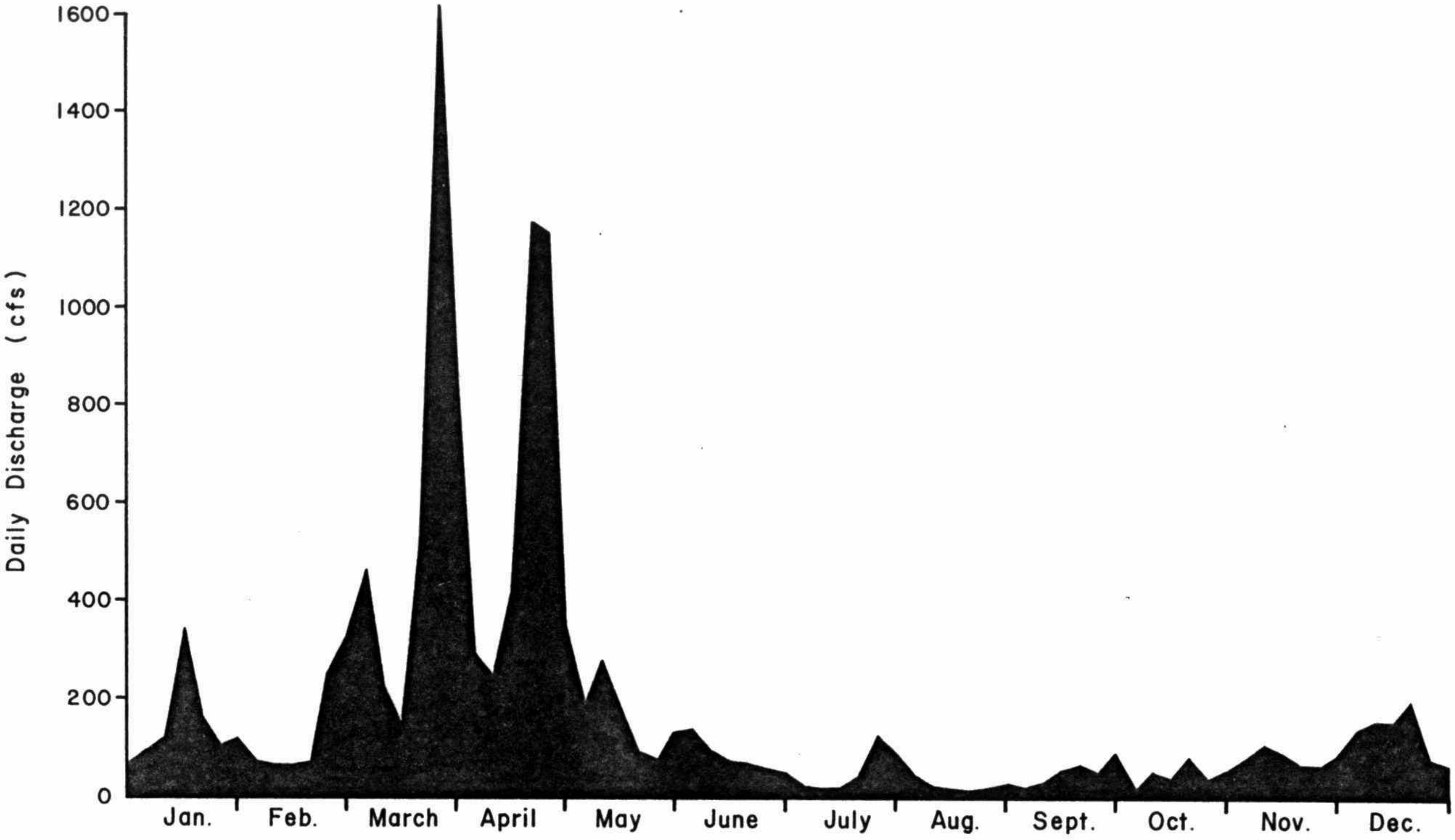

FIG. 2 Daily discharge in cubic feet per second from Jackson's Creek at Peterborough (expressed as the sum of five day intervals) in 1975.

CHAPTER 3

THE PHYSICAL-CHEMICAL LIMNOLOGY OF CHEMUNG LAKE

(1971 - 1976)

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INTRODUCTION

To assess any potential changes in the physical-chemical limnology resulting from the harvesting operation, chemical and biological information was collected at stations in the experimental area in southern Chemung Lake and compared to changes at control stations located in the northern portion of the lake. Sampling was initiated in 1971 prior to the commencement of harvesting operations and continued until the fall of 1976.

DESCRIPTION OF THE STUDY AREA

Chemung Lake (Figure 1), situated approximately 5 kilometers northwest of the City of Peterborough, lies in two physiographic regions, the Peterborough Drumlin Field to the south and the Dummer Moraines to the north. The former are characterized by sandy loam, overlaying Trenton limestone bedrock and the latter are comprised of shallow fill and Black River limestone bedrock. The lake forms part of the Kawartha-Trent system and is some 24 km long with a surface area of approximately 25 km^2. The shoreline is heavily developed with over 900 cottages and residences, numerous resorts and the hamlets of Chemung Park and Bridgenorth.

Chemung Lake is physically divided into two sections at the hamlet of Bridgenorth by a causeway. The portion of the lake south of the causeway which consists largely of land flooded by the creation of the Trent Canal System was selected as the study area for the weed harvesting operation. The lake has four small inlets, three in the southern portion and one in the north. Water from southern Chemung Lake flows into the northern section via a narrow bridge at the east end of the causeway. A single outlet at Harrington Narrows drains into Buckhorn Lake. Morphometric data for the northern and southern sections of the lake are provided in Table 1.

METHODS

Sampling Stations and Sampling Frequency

In selecting the sampling locations, efforts were made to choose representative sites both in the experimental area south of the causeway and in the control area in the northern portion of the lake. The approximate location of the sampling stations is illustrated in Fig. 1 and a description of the sites is provided in Table 2.

Station C-5 in the extreme southern portion of the lake was established in 1973 when harvesting was initiated. However, since data collected at this site showed similar trends to C-4, the station was subsequently dropped in 1975. Similarly, sampling was discontinued at C-3 since the station was considered too remote to provide a suitable control location. Sampling was completed at weekly intervals during the ice-free period between 1972 and 1975. A two week sampling interval was used in 1971 and 1976.

Field Methods

Vertical temperature profiles were determined at each station with a standard mercury thermometer. Light penetration was measured with a Secchi disc. Dissolved oxygen profiles were established using the azide modification of the Winkler method. Samples for pH, free CO_2, alkalinity, and conductivity were collected from 1.0 m below the surface and from 1.0 m above the bottom using a Van Dorn water sampler. Composite samples for chemical determinations were obtained by alternately lowering and raising 1.0 litre glass bottles with restricted inlets to the approximate location of the 1% incident light level (determined as twice the Secchi disc value) while bottom samples were collected with a Van Dorn sampler.

Laboratory Methods

pH was measured using a Corning pH meter. Free CO_2 and alkalinity were determined by titrating separate 100 ml aliquots with 0.02 N NaOH and 0.01 N H_2SO_4 respectively. Conductivity was determined using an Electronic Switch Gear - Model MC-1 Mark V meter. Final recordings were temperature corrected to 25°C and expressed as μmhos/cm . Samples for chlorophyll analysis were filtered under vacuum pressure onto 1.2 μ millipore filters. Chlorophyll and nutrient samples were then transported to the Ministry of the Environment's Division of Laboratories in Toronto for determinations of total phosphorus, nitrogen (free ammonia, total Kjeldahl nitrogen, nitrite and nitrate nitrogen), orthosilicate (molybdate reactive portion of soluble silica expressed as SiO_2), iron, manganese, carbon (organic and inorganic) and chlorophyll *a*. All analyses were performed at the Laboratory Services Branch of the Ministry of the Environment using standard chemical tests. (Outlines of Analytical Methods, 1975).

TABLE 1. Morphometric data for Chemung Lake

Parameter	Northern Chemung Lake	Southern Chemung Lake
Area (ha)	1646	858
Maximum depth (m)	6.7	6.1
Mean depth (m)	2.1	1.8
Volume (m^3)	3.40×10^7	1.58×10^7

TABLE 2. Description of stations and sampling effort

Station	Depth (meters)	Description of Area	Number of times sampled 1971	1972	1973	1974	1975	1976
C-5	< 2	extremely shallow and heavily weeded	-	-	21	19	-	-
C-4	3	entire area with macrophyte growth	10	20	21	19	21	13
C-1	6	deepest part in south, weed-free	11	20	21	19	21	13
C-2	4	scattered weed cover on bottom	11	20	21	19	21	13
C-3	7	deepest part of lake, weed-free	11	20	21	19	-	-

RESULTS AND DISCUSSION

Temperature and Dissolved Oxygen

Temperature differences between surface and bottom strata were generally less than 1°C, indicating the effects of vertical mixing provided by the prevailing southwesterly winds. Mean surface temperatures were similar at all sampling stations, with year to year variations reflecting the prevailing weather conditions (Table 3).

Surface dissolved oxygen concentrations rarely fell below 80% saturation, while occasional supersaturated levels as high as 110% were recorded (Table 2). Oxygen profiles were generally homogeneous with depth, although infrequent reductions did occur in the bottom waters at stations C-1 and C-3, usually during prolonged periods of warm, windless weather. (Fig. 2). Both these stations are deeper (6 and 7 m) and devoid of macrophyte growths which could supply oxygen through the process of photosynthesis.

Ionic Constituents and Free CO_2

Annual mean values for pH, CO_2, alkalinity, conductivity and hardness are provided in Table 4. Seasonal patterns for pH values at all sampling stations were characterized by gradual increases over the summer months from near neutral values in the spring. The most pronounced increases were observed at the two shallow, heavily macrophyte-infested stations (C-4, C-5) where late summer pH values in excess of 9 were recorded. Variations in pH values with depth were insignificant although occasional depressions were noted at the deeper stations. Free CO_2 was usually not detectable in the surface waters during the summer months, indicating complete utilization by the algal and macrophyte communities. Periodic accumulations of free CO_2 in the bottom water at the deeper stations C-1 and C-3, particularly during prolonged stagnant periods, can be attributed to decomposition and respiration processes.

Seasonal trends for alkalinity, conductivity and hardness are illustrated in Figures 3a to 6. These parameters were generally homogeneous

TABLE 3. Mean and extreme values for temperature (°C) and dissolved oxygen (% saturation) in the surface waters of Chemung Lake.

		1971		1972		1973		1974		1975		1976	
Station	Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North													
C-2	Temperature	20.5	13.8-24.9	19.9	11.0-25.0	21.5	11.0-27.0	19.0	9.8-24.3	20.4	11.2-26.0	16.9	9.0-23.2
	Oxygen	90.8	78-110	95.0	75-136	93.9	82-113	94.4	88-108	91	84-104	92	82-114
C-3	Temperature	20.5	14.1-24.5	19.6	11.3-25.6	21.4	11.0-27.0	19.1	7.1-24.0	-		-	
	Oxygen	91.9	78-115	95.0	79-140	90.5	73-108	92.3	85-103	-		-	
South													
C-1	Temperature	20.0	14.1-23.0	19.5	9.8-25.2	21.8	11.5-28.0	18.9	9.8-24.2	20.6	11.2-26.2	17.0	9.2-22.8
	Oxygen	87.1	74-110	92.8	74-100	90.9	83-100	93.6	86-109	89	75-106	90	83-110
C-4	Temperature	20.3	13.7-23.0	19.1	11.0-24.5	21.3	11.5-27.0	18.2	7.1-23.5	20.0	11.2-25.9	17.0	8.8-23.5
	Oxygen	88.7	73-101	94.8	81-108	94.3	81-115	92.9	78-108	91	83-104	94	82-110
C-5	Temperature	-		-		21.8	12.0-26.8	18.7	7.1-23.5	-		-	
	Oxygen	-		-		91.9	75-124	91.4	74-110	-		-	

TABLE 4. Mean and Extreme values for pH, free CO_2 (mg/l), alkalinity (mg/l), conductivity (µmhos/cm^2) and hardness (mg/l) in the surface waters of Chemung Lake.

		1971		1972		1973		1974		1975		1976	
Station	Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North													
C-2	pH	8.1	7.8-8.4	8.2	7.4-8.6	8.4	7.5-8.6	8.6	8.4-8.7	8.5	8.2-8.9	8.4	8.2-8.6
	CO_2	1.7	0-3.6	1.5	0-8.8	0.3	0-7.1	N.D.		N.D.		N.D.	
	Alkalinity	123	118-135	109	97-117	112	91-124	102	82-121	99	67-120	113	99-146
	Conductivity	353	118-445	304	260-366	295	225-353	255	203-344	232	201-283	256	247-270
	Hardness	145	136-152	132	110-142	134	114-152	119	98-150	116	95-154	132	118-183
C-3	pH	8.1	7.4-8.5	8.2	7.8-8.5	8.3	8.0-8.4	8.4	8.4-8.5	-		-	
	CO_2	2.0	0-5.6	0.6	0-4.4	0.4	0-4.9	N.D.		-		-	
	Alkalinity	127	125-129	123	106-130	125	104-139	110	87-125	-		-	
	Conductivity	318	205-405	335	290-412	303	230-351	267	213-338	-		-	
	Hardness	147	144-152	145	132-160	142	124-156	128	100-144	-		-	
South													
C-1	pH	8.1	7.6-8.3	8.3	7.5-8.6	8.4	7.9-8.6	8.5	8.3-8.6	8.5	8.2-8.6	8.4	8.3-8.6
	CO_2	1.9	0-3.8	1.2	0-8.9	0.1	0-2.8	N.D.		N.D.		N.D.	
	Alkalinity	130	121-148	116	104-126	123	106-135	116	96-133	117	99-137	116	107-129
	Conductivity	337	205-465	323	269-384	305	241-379	282	241-339	262	230-315	269	212-290
	Hardness	157	144-170	141	116-162	143	124-156	134	112-156	130	105-158	137	120-202
C-4	pH	8.1	7.8-8.5	8.3	7.8-8.7	8.5	8.3-9.1	8.5	8.3-8.5	8.5	8.2-8.8	8.5	8.3-8.6
	CO_2	2.5	0-5.4	0.8	0-4.7	0.1	0-0.4	N.D.		N.D.		N.D.	
	Alkalinity	126	114-148	109	92-126	119	93-156	112	88-140	111	81-139	111	98-125
	Conductivity	313	180-490	299	230-407	292	204-391	280	215-339	253	198-311	258	239-295
	Hardness	152	136-168	134	112-156	136	98-164	130	99-158	126	97-158	125	115-143
C-5	pH	-		-		8.3	8.2-9.1	8.7	8.3-9.5	-		-	
	CO_2			-		0.1	0-1.2	N.D.		-		-	
	Alkalinity	-		-		106	70-158	105	61-157	-		-	
	Conductivity	-		-		270	177-466	256	157-360	-		-	
	Hardness	-		-		127	92-172	117	77-188	-		-	

with depth but values decreased over the summer months. Greatest fluctuations were observed at the two shallow stations (C-4 and C-5) with early June maxima and minimum values by August. Annual mean values for alkalinity, conductivity and hardness decreased progressively at all sampling stations over the six year study period.

Concentrations of the major ions are summarized in Table 5. As expected for the bicarbonate-dominated waters of Chemung Lake, the cations were present in the following sequence: $Ca^{++} > Mg^{++} > Na^{+} > K+$ with calcium dominant. Concentrations of Na, Mg and K were similar at all sampling stations and although annual means showed some year to year fluctuations, no definite trends were apparent. Calcium concentrations were highest in the spring and decreased gradually over the summer months (Fig. 6, 7a and 7b) particularly at the shallow water stations C-4 and C-5. Mean annual calcium concentrations at all stations showed a progressive decrease between 1971 and 1976 similar to the previously mentioned trend in alkalinity, conductivity and hardness values. The decrease in these parameters can perhaps be attributed to the utilization of bicarbonate by the plant populations, following depletion of free CO_2, with the resultant deposition of calcium carbonate or marl (Hutchinson 1975).

Nutrient Considerations

Mean and extreme values for iron, manganese, orthosilicate and organic and inorganic carbon are provided in Table 6. Iron and manganese levels were low at all stations throughout the study period. Maximum mean values for iron were obtained at stations C-2, C-1 and C-4 in 1975, while the lowest concentrations were recorded in 1976. Seasonal variations in orthosilicate concentrations are illustrated in figures 8a, 8b and 9. Gradual increases in orthosilicate concentrations throughout the summer months occurred at all sampling locations, undoubtedly due to the decline in diatom populations following the spring pulses. Highest seasonal mean values (2.3 to 4.7 mg/l) were attained in 1971. Values were lower throughout the balance of the study period and showed little year to year variation.

TABLE 5. Mean and Extreme values for calcium (mg/l), sodium (mg/l), magnesium (mg/l) and potassium (mg/l) in the surface waters of Chemung Lake.

		1971		1972		1973		1974		1975		1976	
Station	Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North													
C-2	Ca	52	49-55	47	38-54	45	34-62	40	33-48	38	30-51	42	38-46
	Na	3.7	3-4	3.5	3-4	4.0	3-4	4.5	4.1-5.0	4.3	4.1-4.6	4.8	4.4-5.2
	Mg	3.6	3-5	3.7	1-7	5.1	2-11	4.4	4-7	4.8	4-6	4.9	3.8-9.5
	K	1.1	0.8-1.3	0.9	0.4-1.5	1.4	1.1-10	1.4	1.2-1.7	1.3	1.1-1.5	1.3	1.2-1.3
C-3	Ca	54	52-57	51	36-56	51	40-71	46	34-53	-		-	
	Na	3.2	3-4	3.4	2-4	3.5	3-4	3.7	3.1-4.3	-		-	
	Mg	2.6	2-4	4.1	1-12	4.6	2-9	2.8	1-4	-		-	
	K	1.0	0.8-1.1	0.8	0.4-1.1	1.3	1.1-2.6	1.0	0.1-1.4	-		-	
South													
C-1	Ca	56	50-61	49	40-55	49	40-67	46	38-53	44	34-54	44	38-48
	Na	4.0	4	3.8	3-5	4.1	4-5	4.7	4.1-5.3	4.5	4.3-4.7	4.8	4.5-5.3
	Mg	4.2	4-5	4.5	2-9	5.4	2-10	4.6	3-6	5.3	5.0-7.	5.2	4.8-6.0
	K	1.2	1.0-1.3	0.9	0.3-1.3	1.5	1.1-2.9	1.5	0.4-1.9	1.3	1.2-1.6	1.3	1.1-1.3
C-4	Ca	54	47-61	46	37-54	47	34-69	44	33-56	42	30-54	42	35-49
	Na	4.1	4-5	3.8	3-5	4.0	3-5	4.3	3-5.8	4.4	4.1-4.6	4.4	1.2-5.1
	Mg	4.2	4-5	4.4	3-7	5.6	2-12	4.7	3-7	5.2	4-6	5.1	4.5-5.5
	K	1.1	0.8-1.3	0.8	0.2-1.2	1.3	0.8-2.5	1.3	0.1-1.8	1.2	0.8-1.2	1.2	1.0-1.3
C-5	Ca					41	26-75	37	22-64				
	Na					3.9	3-6	4.4	3.7-6.6				
	Mg					6.1	4-12	5.2	3-8				
	K					1.3	0.8-4	0.7	<0.1-1.5				

TABLE 6. Mean and Extreme values for iron (mg/l), manganese (mg/l), silica (mg/l), inorganic and organic carbon (mg/l) in the euphotic zone of Chemung Lake.

		1971		1972		1973		1974		1975		1976	
Station	Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North													
C-2	Fe	0.05	0.0-0.15	0.05	0.04-0.10	0.09	0.05-0.10	0.05	0.03-0.10	0.06	0.05-0.20	0.01	0.01-0.55
	Mn	0.02	0.0-0.05	0.04	0.03-0.10	0.04	0.02-0.05	0.04	0.01-0.04	0.05	0.03-0.13	0.06	0.02-0.08
	SiO_2	4.7	3.0-7.2	1.5	0.3 -2.4	1.3	0.1 -2.2	0.9	0.4 -1.4	1.3	0.9 -2.3	1.3	0.2 -2.6
	Inorg. Carbon	25.3	19.2-32.3	21.7	15-27.5	21.7	8-27	23.5	19-29	22.0	17-31	24.0	19-26
	Org. Carbon	10.9	2.0-17.0	11.6	5-18	13.6	5-25	8.7	6-12	10.0	7-12	10.0	5-17
C-3	Fe	0.04	0.0-0.10	0.08	0.05-0.50	0.06	0.05-1.50	0.05	0.05-0.06				
	Mn	0.01	0.0-0.05	0.05	0.02-0.08	0.03	0.02-0.05	0.04	0.01-0.04				
	SiO_2	4.4	1.2-8.4	2.9	0.9 -4.8	1.3	0.3 -2.2	0.9	0.4 -1.5	-		-	
	Inorg. Carbon	25.8	18.0-28.0	24.6	17-32	24.7	18-30	27.1	21-34				
	Org. Carbon	11.5	2.0-20.5	12.7	7-19	13.2	6-28	7.2	5-9				
South													
C-1	Fe	0.05	0.0-0.15	0.07	0.05-0.50	0.06	0.05-0.10	0.05	0.05-0.10	0.13	0.05-0.75	0.03	0.02-0.10
	Mn	0.02	0.0-0.05	0.04	0.02-0.06	0.04	0.02-0.07	0.04	0.03-0.04	0.06	0.03-0.17	0.05	0.02-0.06
	SiO_2	3.2	2.5-5.0	1.1	0.1 -2.2	1.4	0.1 -2.8	1.2	0.4 -2.1	1.4	0.7 -2.2	1.2	0.3 -2.2
	Inorg. Carbon	27.5	21.5-35.0	22.6	17-21	24.3	13-28	27.4	23-32	26.0	21-32	26.0	18-31
	Org. Carbon	11.4	2.0-19.5	12.6	2-19	13.6	6-24	9.8	7-18	9.0	5-15	9.0	1-20
C-4	Fe	0.06	0.0-0.20	0.05	0.05-0.15	0.05	0.05	0.06	0.04-0.10	0.09	0.05-0.40	0.03	0.02-0.05
	Mn	0.05	0.0-0.33	0.04	0.02-0.07	0.04	0.02-0.07	0.04	0.04-0.05	0.05	0.03-0.08	0.04	0.02-0.08
	SiO_2	2.3	1.3-3.6	1.0	0.03-2.2	1.5	0.1 -3.0	1.0	0.2 -1.9	1.5	0.8 -2.5	1.0	0.1 -2.2
	Inorg. Carbon	27.0	22.0-34.2	21.6	13-27	22.4	7-30	26.1	20-35	24.0	16-31	25.0	14-30
	Org. Carbon	10.2	1.5-20.5	13.9	9-18	15.7	8-34	9.8	7-13	10.0	6-13	9.0	6-12
C-5	Fe					0.06	0.05-0.15	0.08	0.05-0.20				
	Mn					0.04	0.02-0.08	0.04	0.03-0.04				
	SiO_2	-		-		2.5	0.2 -4.4	1.4	0.1 -2.7	-		-	
	Inorg. Carbon					20.2	10-33	22.4	11-40				
	Org. Carbon					16.9	7-34	12.5	9-17				

The total inorganic carbon concentration in fresh waters depends on the pH, which is governed largely by the buffering reactions of carbonic acid and the amount of bicarbonate and carbonate derived from the weathering of rocks (Wetzel 1975). In the well buffered waters of Chemung Lake, total inorganic carbon levels were high, providing an adequate supply for algal and macrophyte photosynthetic metabolism.

Mean and extreme values for phosphorus and nitrogen are summarized in Table 7. Although phosphorus concentrations fluctuated widely throughout the ice-free periods, (Figs. 9, 10a, 10b) seasonal mean values show a progressive increase in phosphorus levels from northern to southern Chemung Lake, both prior to and following the commencement of harvesting operations. Mid-summer euphotic zone nitrate nitrogen depletions, characteristic of productive environments were observed at all sampling stations. Mean total Kjeldahl concentrations were high, particularly at the shallow stations C-4 and C-5, again reflecting a highly productive environment.

Phosphorus has long been regarded as the essential and often limiting requirement for plant growth in aquatic environments (Hasler and Einsele, 1948; Sawyer, 1947; Edmonson, 1970). Hutchison (1957) indicated that phosphorus may limit production when the N/P ratio is high (total Kjeldahl plus nitrate to total phosphorus) whereas nitrogen would be expected to limit production when the ratio is low i.e. less than 9:1 (by weight). Nitrogen/phosphorus ratios in Chemung Lake (Table 8) were high, suggesting that phosphorus may be the key factor controlling planktonic production in the lake. In view of this fact, the continuous removal of phosphorus via harvesting of aquatic vegetation represents a potential method of reducing phosphorus levels and resultant production in the lake. Nutrient budget data (Chapter 2) show that harvesting operations in 1975 resulted in the removal of 47% of the gross annual phosphorus loading and 92% of the net phosphorus retained in the lake. Although mean annual euphotic zone phosphorus concentrations in southern Chemung Lake show a slight reduction between 1971 and 1976 (Table 7), this decrease cannot be attributed to the harvesting operation since similar trends were apparent in the control

TABLE 7. Nitrogen (mg/l) and phosphorus (μg/l) concentrations in the euphotic zone of Chemung Lake

Station	Para-meter	1971		1972		1973		1974		1975		1976	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North													
C-2	TP	23	12-38	23	15-40	18	6-28	27	11-46	19	10-28	19	12-26
	NH_3	<0.01	<0.01-0.01	0.06	<0.01-0.14	0.05	<0.01-0.60	0.04	<0.01-0.13	0.06	<0.01-0.14	0.03	<0.01-0.07
	TKN	0.51	0.35-0.70	0.55	0.43-0.64	0.51	0.25-0.64	0.62	0.44-0.77	0.59	0.44-0.80	0.56	0.41-0.76
	NO_2	0.003	<0.001-0.005	0.004	0.001-0.008	0.002	<0.001-0.006	0.002	<0.001-0.005	0.002	<0.001-0.009	0.003	<0.001-0.007
	NO_3	0.03	0.01-0.23	0.04	<0.01-0.22	0.01	<0.01-0.03	0.02	<0.01-0.07	0.02	<0.01-0.13	0.03	<0.01-0.13
C-3	TP	26	16-89	21	14-29	16	1-28	20	11-31				
	NH_3	0.02	<0.01-0.09	0.04	<0.01-0.27	0.05	<0.01-0.25	0.05	<0.01-0.47				
	TKN	0.55	0.40-0.80	0.58	0.27-1.58	0.48	0.11-0.81	0.59	0.43-1.2				
	NO_2	0.003	<0.001-0.006	0.003	0.001-0.007	0.002	<0.001-0.004	0.002	<0.001-0.004				
	NO_3	0.03	<0.01-0.25	0.03	<0.01-0.27	0.02	<0.01-0.13	0.03	<0.01-0.17				
South													
C-1	TP	27	16-40	24	14-41	24	11-35	31	12-46	23	10-35	23	16-32
	NH_3	0.02	0.01-0.05	0.03	<0.01-0.10	0.05	<0.01-0.50	0.03	0.01-0.09	0.07	0.01-0.19	0.05	0.01-0.16
	TKN	0.53	0.38-0.79	0.55	0.37-0.68	0.56	0.38-0.65	0.64	0.46-0.80	0.60	0.46-0.81	0.59	0.46-0.77
	NO_2	0.003	0.001-0.007	0.004	0.002-0.010	0.022	0.001-0.005	0.003	<0.001-0.009	0.003	0.001-0.012	0.003	<0.001-0.009
	NO_3	0.04	<0.01-0.30	0.04	<0.01-0.27	0.02	<0.01-0.08	0.03	<0.01-0.17	0.03	<0.01-0.16	0.05	<0.01-0.18
C-4	TP	32	21-47	30	20-82	26	4-48	33	17-50	23	14-31	23	14-34
	NH_3	0.03	<0.01-0.18	0.03	<0.01-0.11	0.07	0.01-0.33	0.04	<0.01-0.23	0.05	<0.01-0.10	0.04	<0.01-0.09
	TKN	0.60	0.38-1.0	0.62	0.33-0.85	0.63	0.27-0.94	0.72	0.50-1.2	0.62	0.45-0.97	0.56	0.30-0.76
	NO_2	0.003	0.001-0.009	0.004	0.001-0.008	0.002	<0.001-0.005	0.003	<0.001-0.008	0.003	0.001-0.010	0.003	<0.001-0.007
	NO_3	0.02	<0.01-0.05	0.03	<0.01-0.21	0.02	<0.01-0.13	0.03	<0.01-0.30	0.03	<0.01-0.13	0.02	<0.01-0.10
C-5	TP					32	8-57	38	11-48				
	NH_3					0.13	<0.01-0.68	0.07	<0.01-0.23				
	TKN					0.82	0.28-1.40	0.82	0.46-1.1				
	NO_2					0.004	0.001-0.032	0.002	0.001-0.005				
	NO_3					0.02	<0.01-0.22	0.01	<0.01-0.06				

TABLE 8. N/P ratios in Chemung Lake, 1971 to 1976

Station	1971	1972	1973	1974	1975	1976
C-1	21	26	24	22	27	28
C-2	24	26	29	24	32	31
C-3	22	29	31	31	-	-
C-4	19	22	25	23	28	25
C-5	-	-	26	22	-	-

TABLE 9. Total nitrogen, phosphorus and iron (mg/g dry wt.) in sediment samples collected in 1971 from Chemung Lake

Station	Nitrogen	Phosphorus	Iron
C-1	20	1.2	14
C-2	13	1.2	15
C-3	19	1.2	9
C-4	27	1.9	11

TABLE 10. Mean and Extreme values for Chlorophyll a (μg/l) and secchi disc (m) in Chemung Lake.

		1971		1972		1973		1974		1975		1976	
Station	Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North													
C-2	Chlorophyll a	6.0	1.8-11.2	3.3	1.0-6.2	2.7	0.7-4.5	2.7	0.4-4.5	5.5	2.3-7.4	6.9	2.6-13.0
	Secchi disc	2.2	1.3-4.0	2.8	2.0-4.0	2.2	1.4-3.0	1.8	1.2-3.0	1.6	1.1-2.5	1.7	1.1-2.2
C-3	Chlorophyll a	6.1	1.2-9.6	6.1	1.0-11.0	2.6	0.8-4.2	2.2	0.5-4.0	-		-	
	Secchi disc	1.8	1.4-2.2	2.1	1.2-3.0	2.6	1.7-5.5	2.3	1.5-3.1				
South													
C-1	Chlorophyll a	3.3	0.5-5.8	3.4	1.2-8.0	3.2	1.0-6.9	2.5	0.3-4.7	6.6	1.5-11.0	5.9	1.9-10.0
	Secchi disc	2.7	1.9-5.7	3.0	1.9-5.0	2.2	1.4-4.0	1.8	1.0-3.6	1.6	1.1-3.0	1.8	1.2-3.5
C-4	Chlorophyll a	4.4	0.6-8.5	3.7	1.2-8.0	4.0	1.0-8.6	3.7	0.1-6.5	7.1	3.7-12.0	6.6	2.5-12
	Secchi disc	2.0	1.6-2.6	2.4	2.0-3.0	1.9	1.5-2.9	1.5	1.1-2.3	1.4	1.0-2.2	1.7	1.1-2.7
C-5	Chlorophyll a	-		-		3.7	0.9-9.0	3.0	0.3-5.9	-		-	
	Secchi disc					to bottom		1.4	1.1-1.7				

stations in the northern section of the lake. Several authors, (Syers, Harris and Armstrong 1973; Lee 1970) suggest that sediment phosphorus can become available through resuspension following turbulent mixing with overlying waters in shallow lakes. Sediment phosphorus in Chemung Lake (Table 9) may thus provide a significant source of internal loading. Since aquatic plants are generally believed to obtain their phosphorus both through their foliar and root structures (Denny 1972; Bristow and Whitcombe 1971) it is apparent that harvesting would have to be continued over an extended period of time before significant reductions in sediment and ambient phosphorus levels can be achieved.

Chlorophyll a and Secchi Disc

Megard (1970) demonstrated that integral photosynthesis is a complex function of chlorophyll a concentrations and suggested that chlorophyll a concentrations in the water can be used as an index of algal population densities. Chlorophyll a concentrations in Chemung Lake fluctuated widely throughout the ice-free periods as illustrated in figures 12a and 12b. Annual mean values ranged from 2.5 to 7.1 µg/l, reflecting low to moderately high algal levels (Table 10). In southern Chemung Lake (station C-1 and C-4) mean chlorophyll a concentrations were remarkably similar between 1971 and 1974 but increased sharply in 1975 and 1976. In northern Chemung, high concentrations of chlorophyll a were recorded in 1971 as well as in 1975 and 1976. Since increased chlorophyll a concentrations were observed both in the experimental and control areas of Chemung Lake in 1975 and 1976, definite conclusions regarding the effects of harvesting on algal levels cannot be made. However, changes in algal biomass and community structure will be reviewed in more detail in a subsequent chapter.

CONCLUSIONS

Mean seasonal values for alkalinity, conductivity, hardness and calcium decreased progressively at all sampling stations over the six year study period possibly as a result of bicarbonate utilization by the plant communities. Total phosphorus showed a similar downward trend, while chlorophyll a concentrations increased sharply in 1976 and 1976. Since these trends were observed both in the experimental area and at the control stations in Northern Chemung, it can be concluded that harvesting of aquatic vegetation has to date had no apparent effect on water quality.

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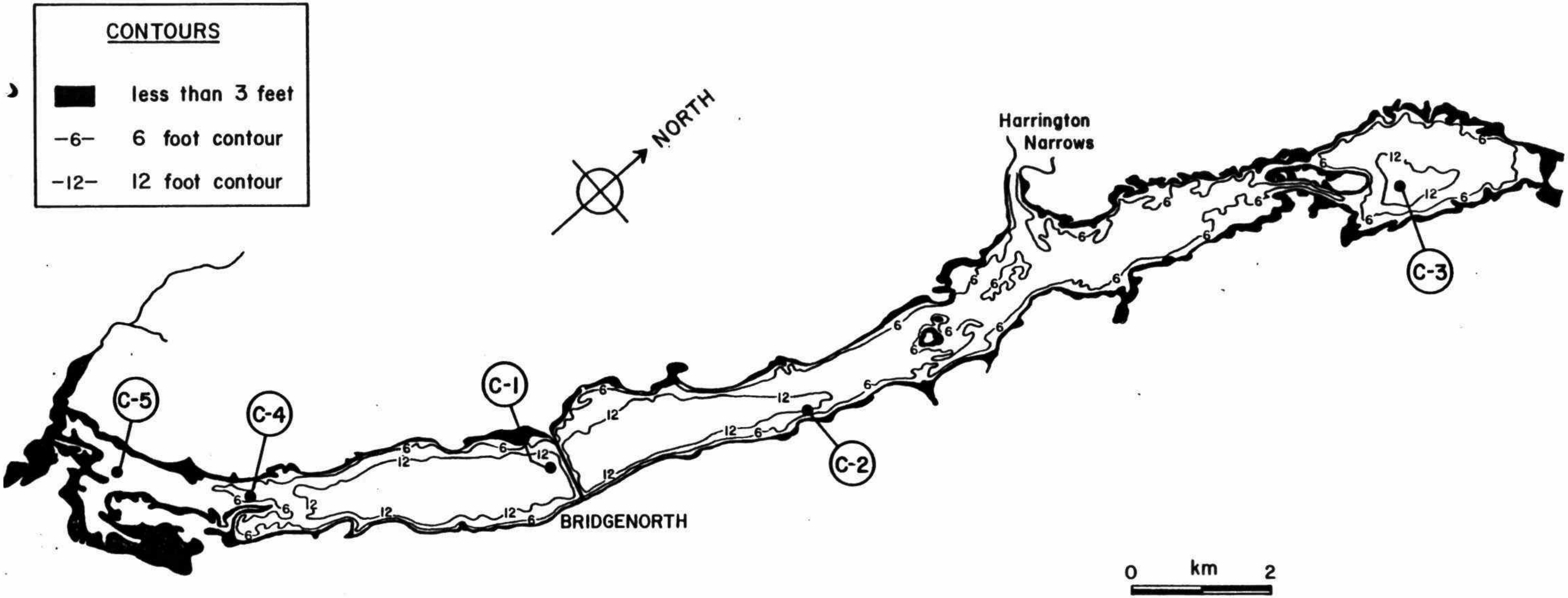


FIG. I Morphometric map of Chemung Lake showing sampling station location.

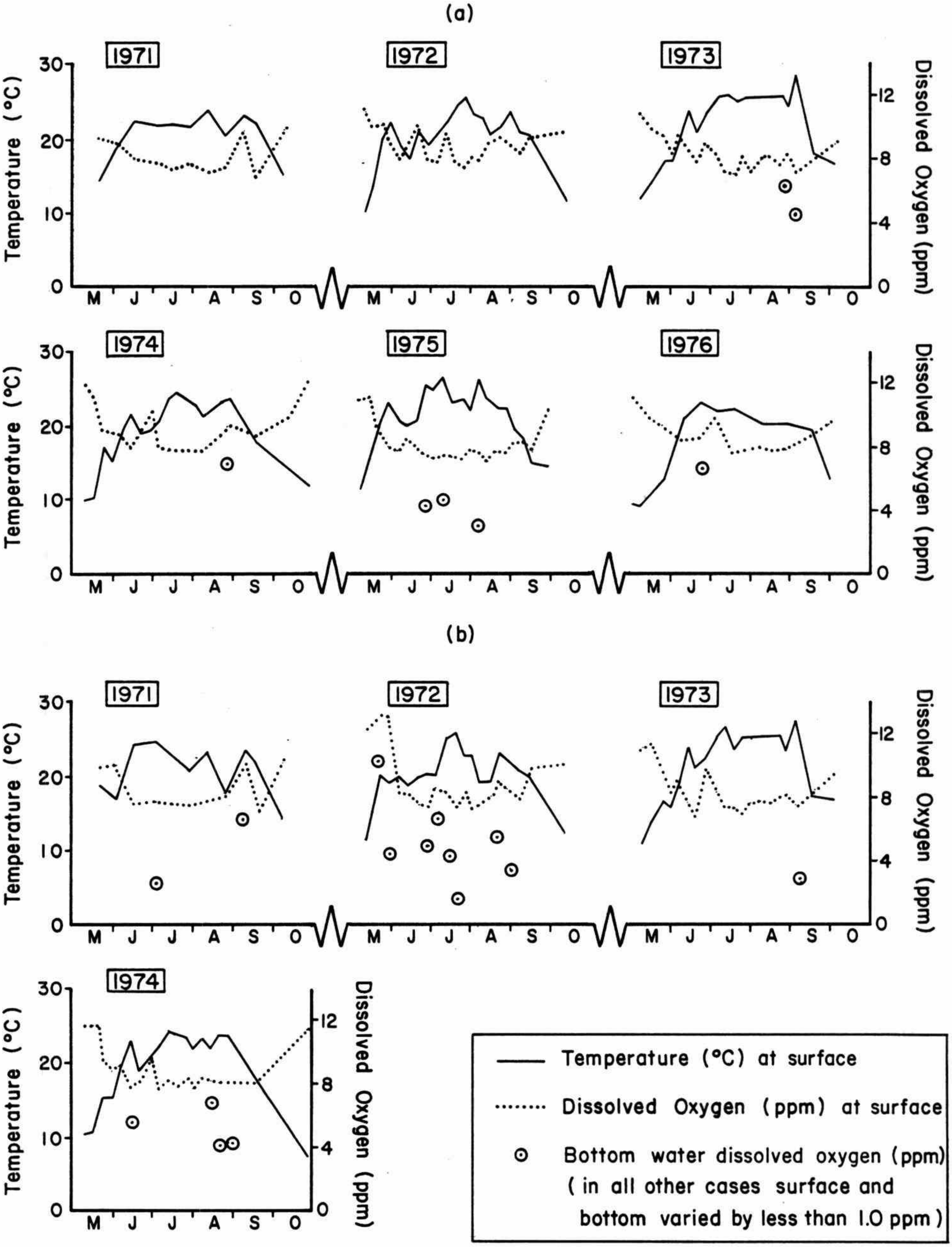


FIG. 2: Seasonal temperature (°C) and dissolved oxygen (ppm) fluctuations in Chemung Lake at (a) C-1 and (b) C-3, from May to October.

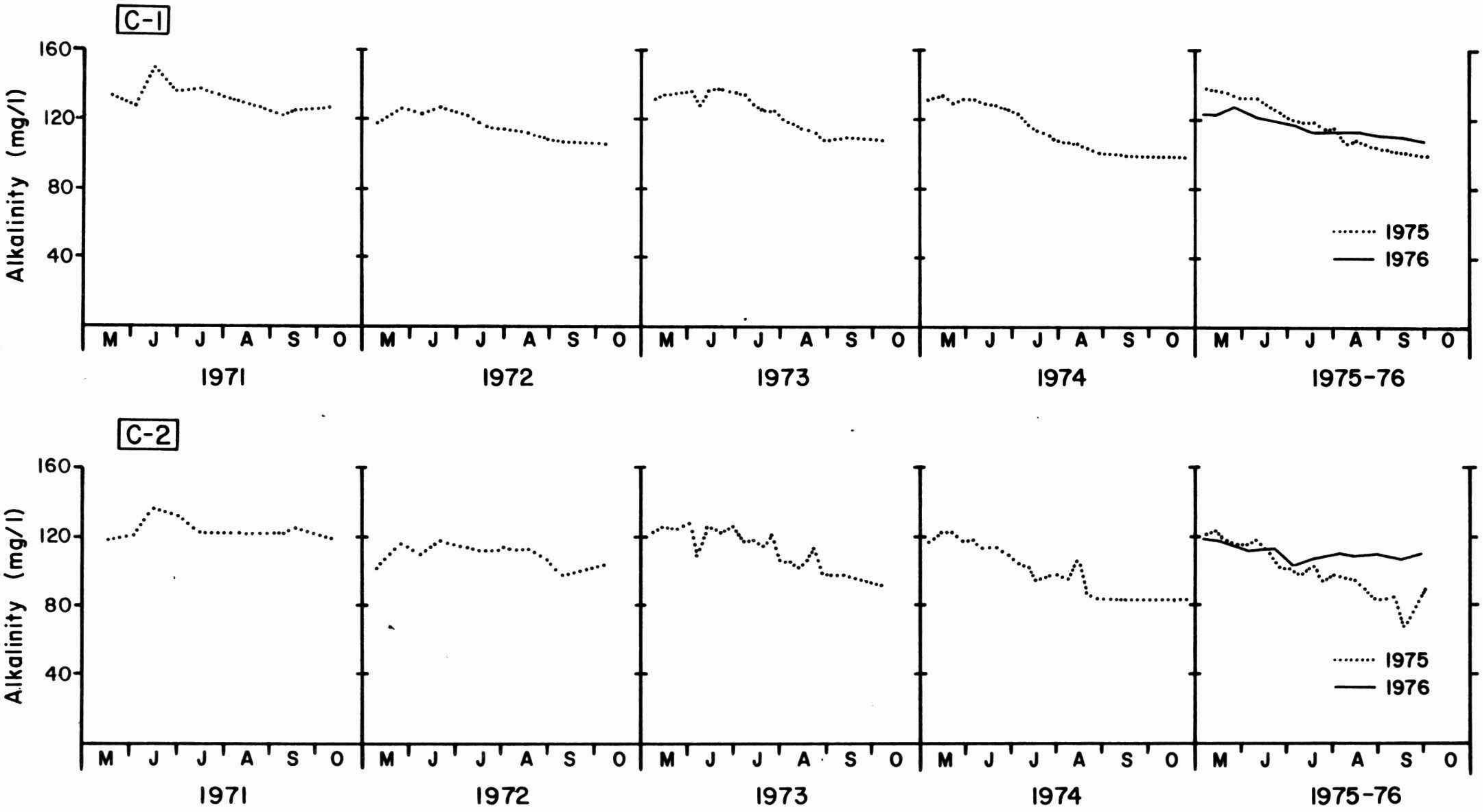


FIG. 3a: Alkalinity (mg/l) in Chemung Lake at stations C-1 and C-2 from May to October, 1971 to 1976.

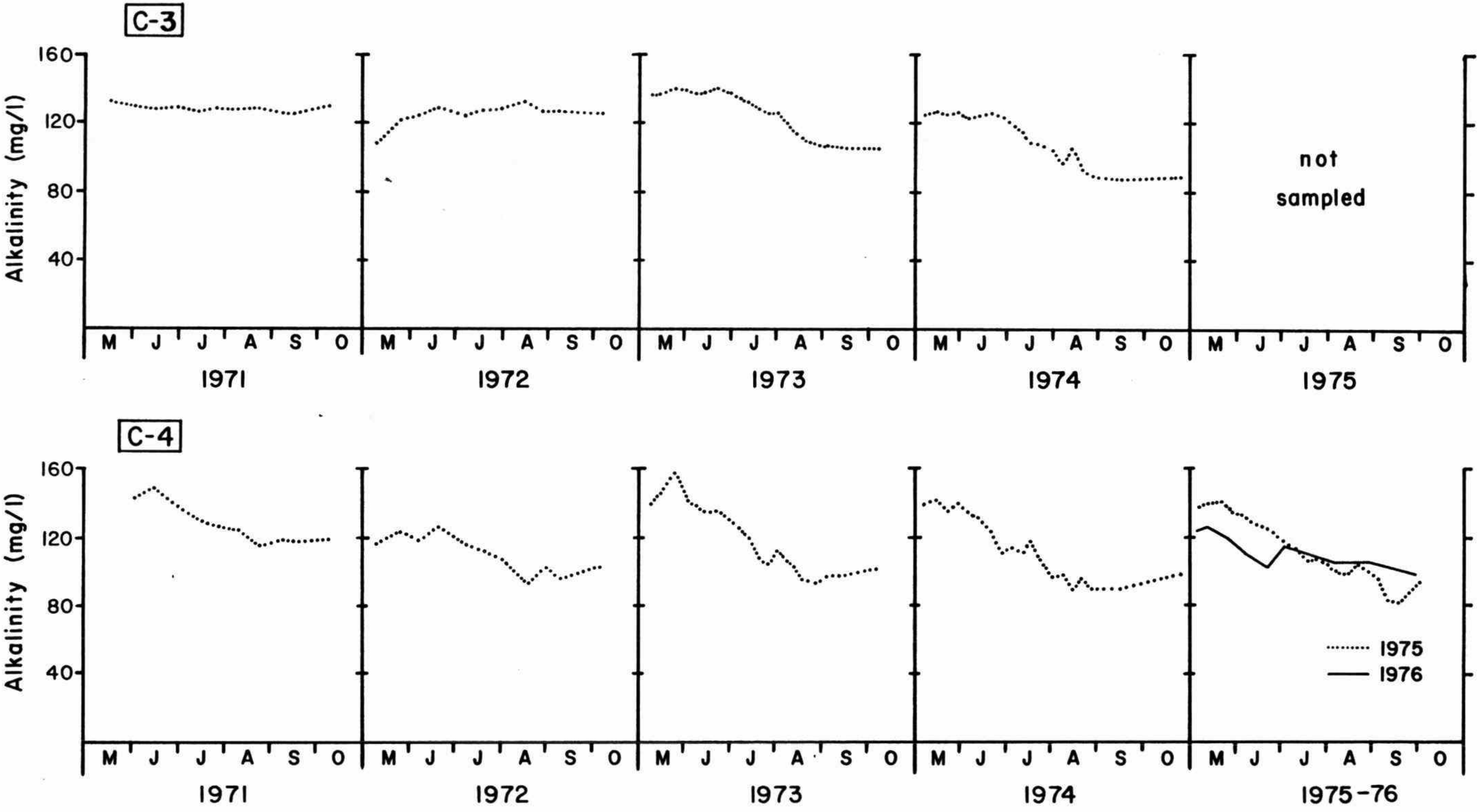


FIG. 3b: Alkalinity (mg/l) in Chemung Lake at stations C-3 and C-4 from May to October, 1971 to 1976.

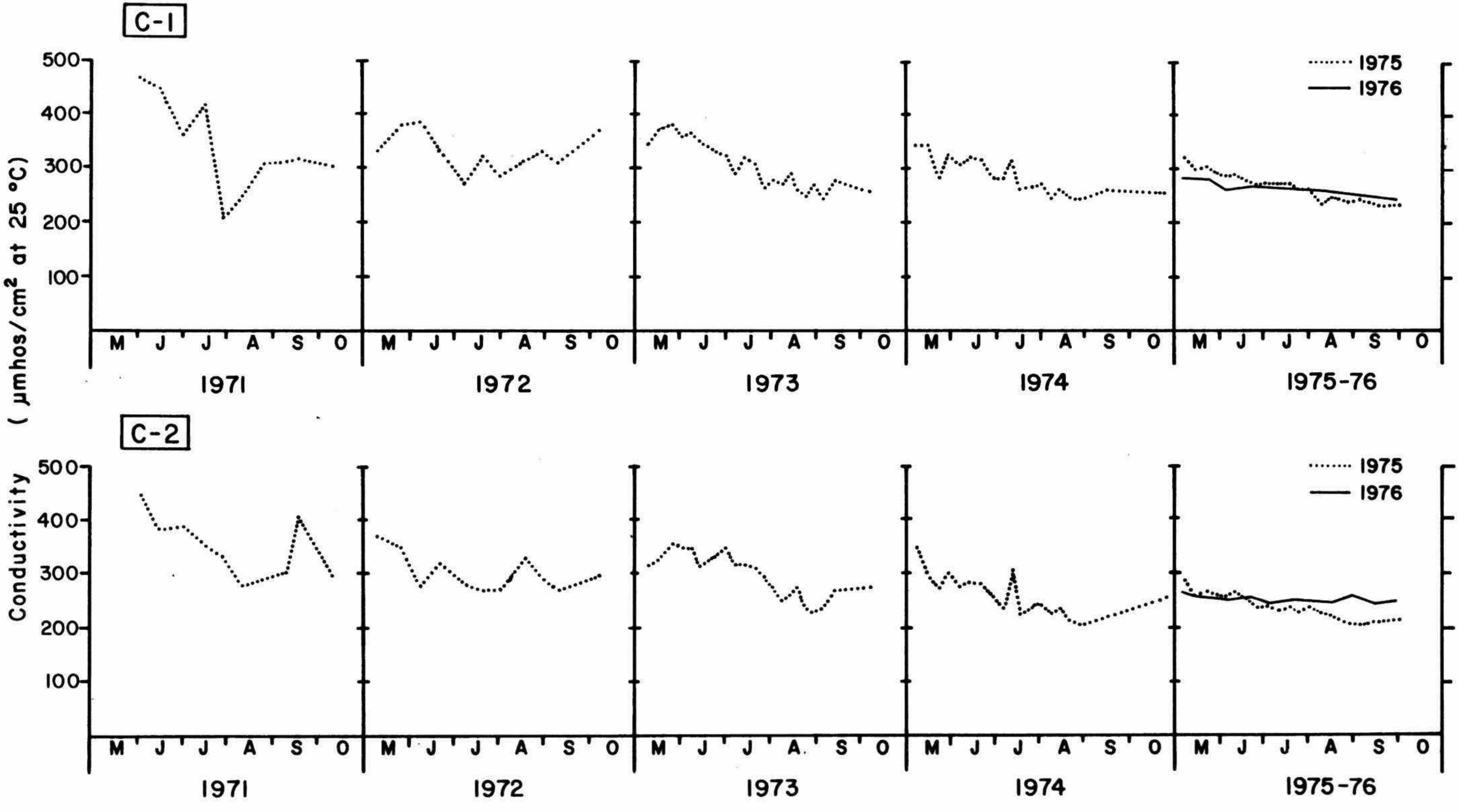


FIG. 4a: Conductivity (µmhos/cm² at 25 °C) in Chemung Lake at C-1 and C-2 from May to October, 1971 to 1976.

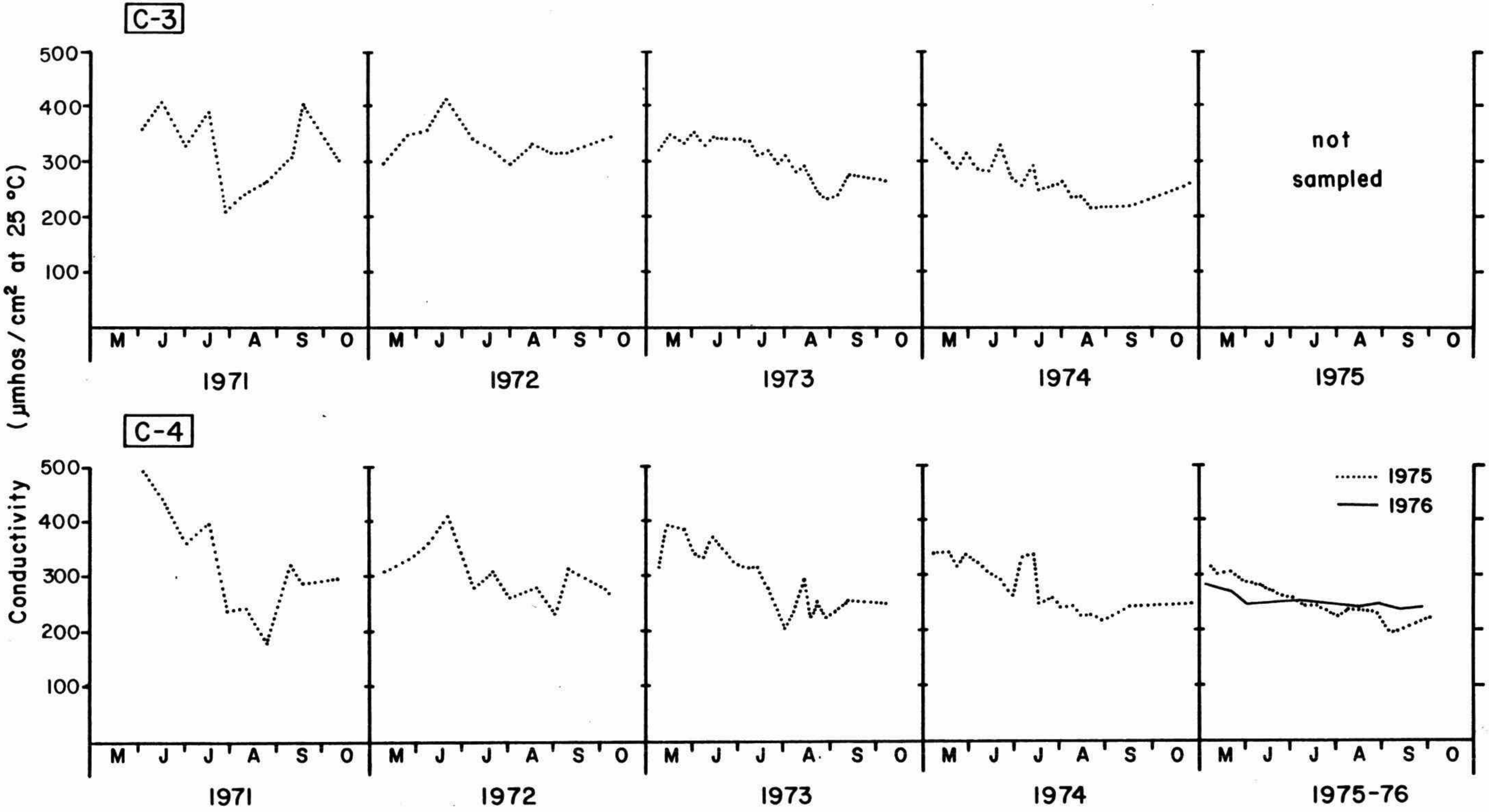
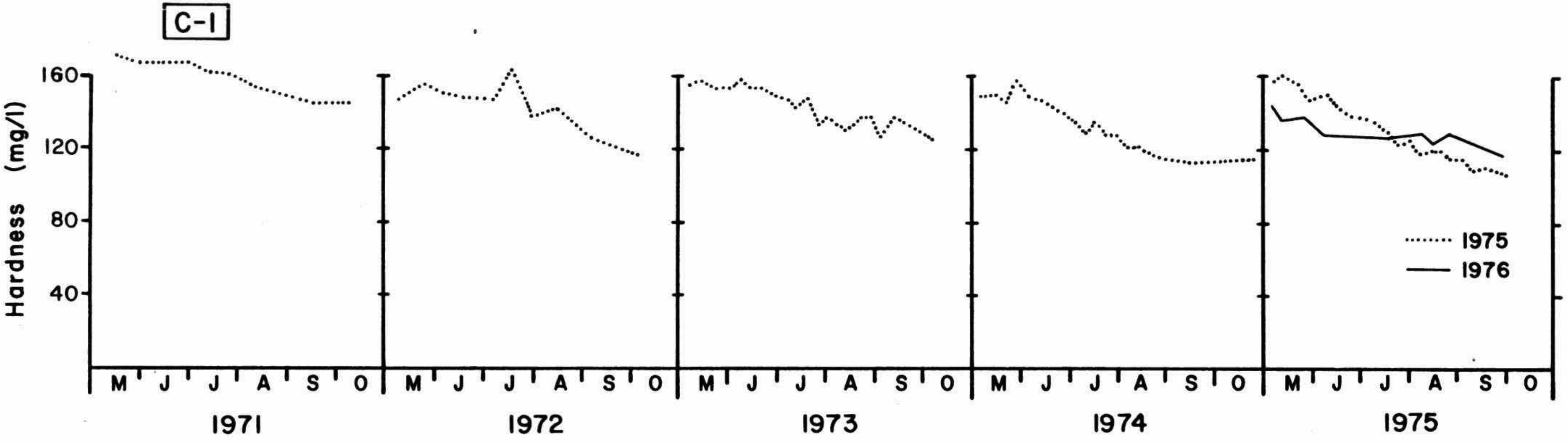


FIG. 4b: Conductivity (μmhos/cm² at 25 °C) in Chemung Lake at C-3 and C-4 from May to October, 1971 to 1976.



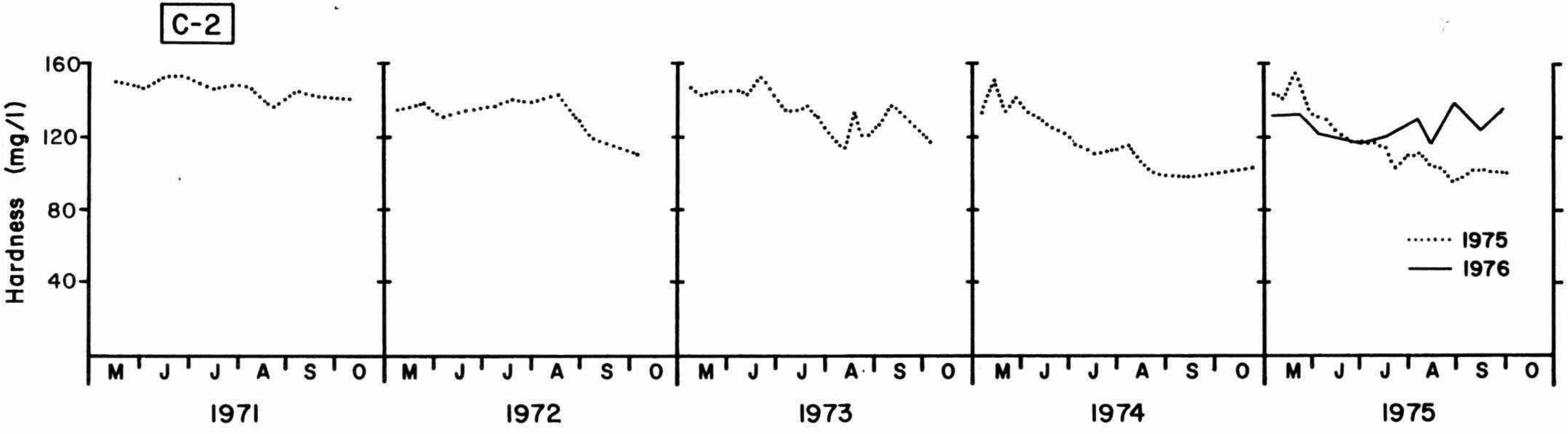


FIG. 5a: Total hardness (mg/l) in Chemung Lake at stations C-1 and C-2 from May to October, 1971 to 1976.

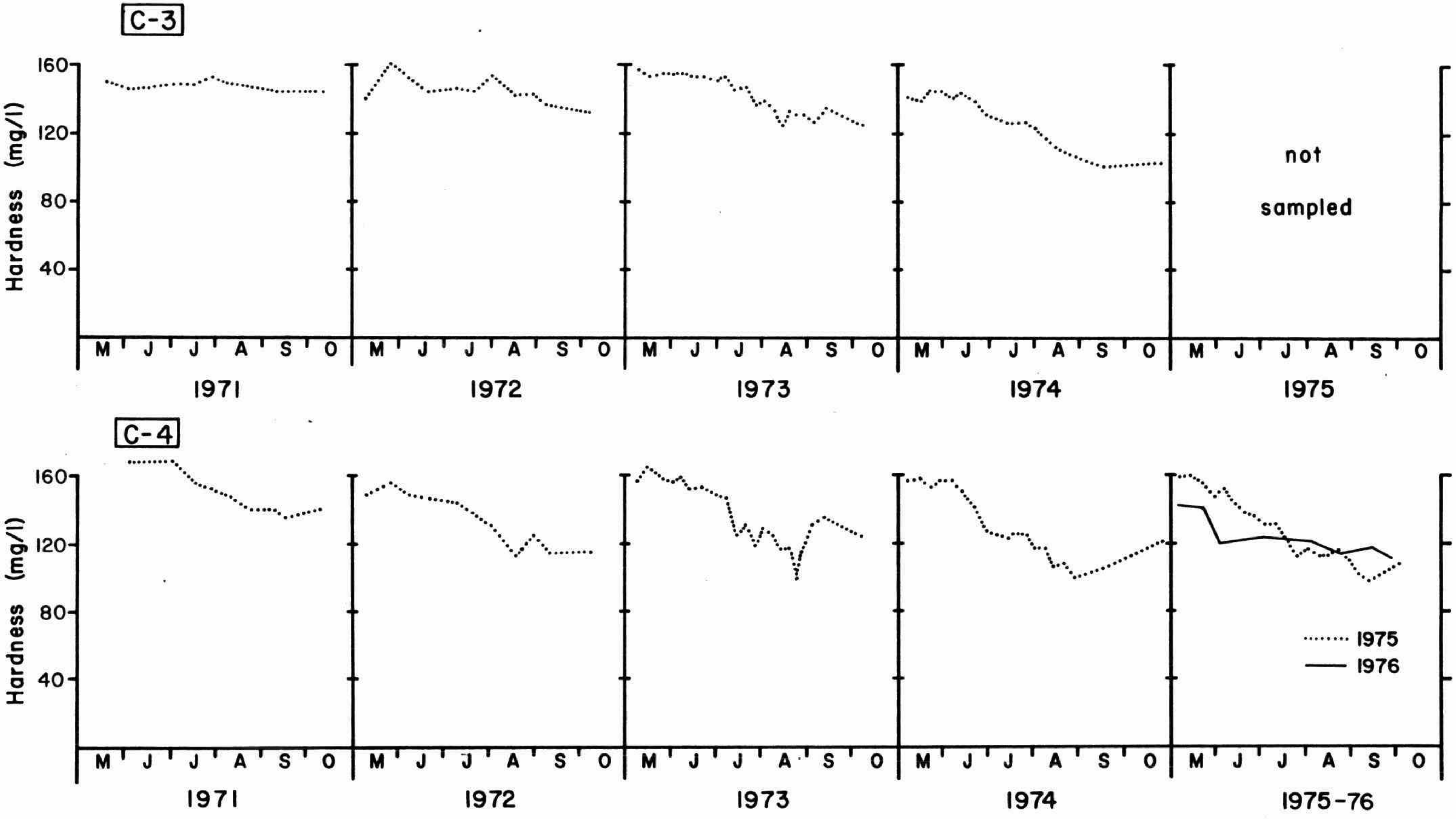


FIG. 5b: Total hardness (mg/l) in Chemung Lake at stations C-3 and C-4 from May to October, 1971 to 1976.

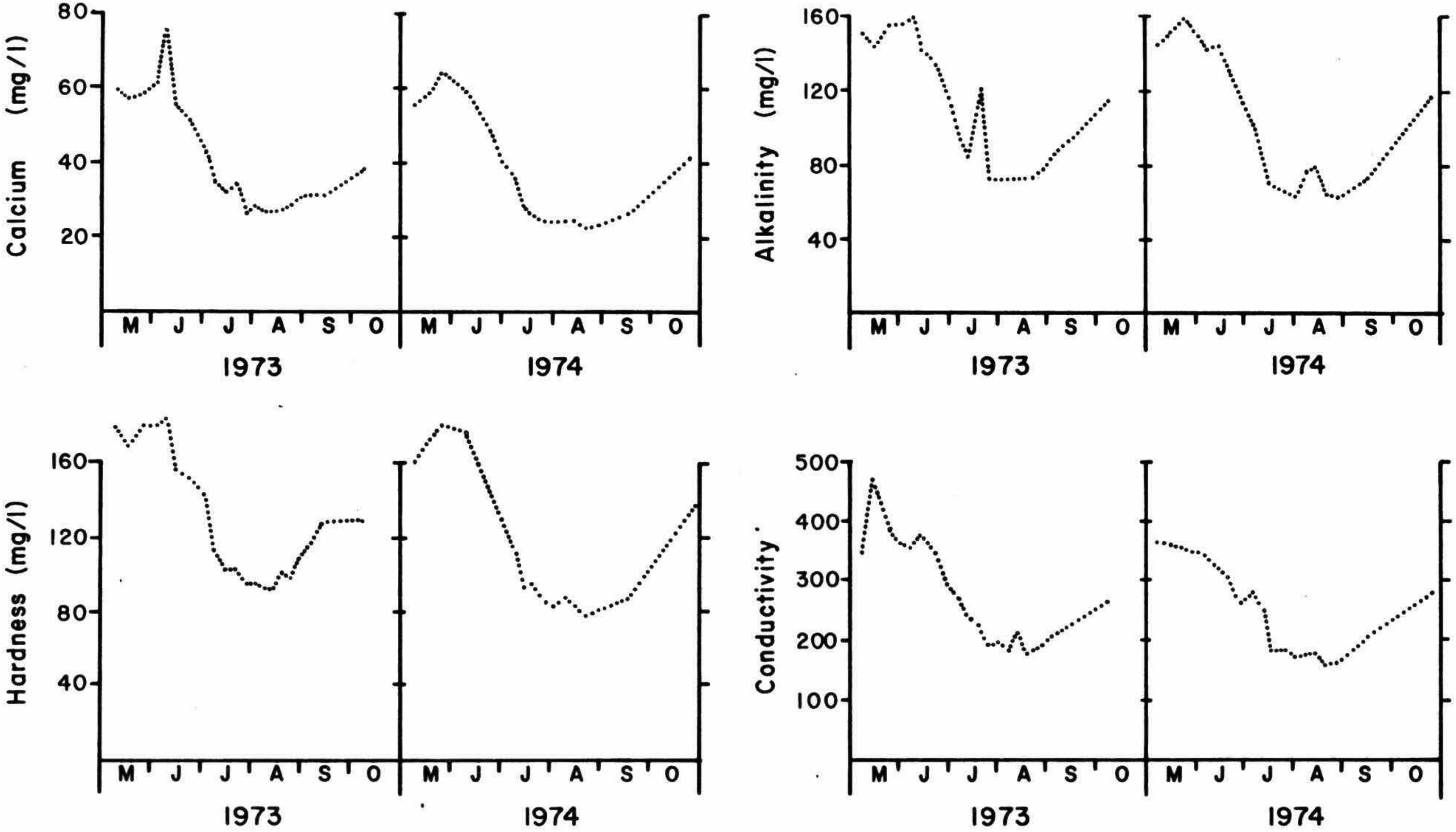


FIG. 6 Calcium (mg/l) concentrations, alkalinity (mg/l), total hardness (mg/l), and conductivity (μmhos/cm^2 at 25 °C) in Chemung Lake at station C-5 in 1973 and 1974.

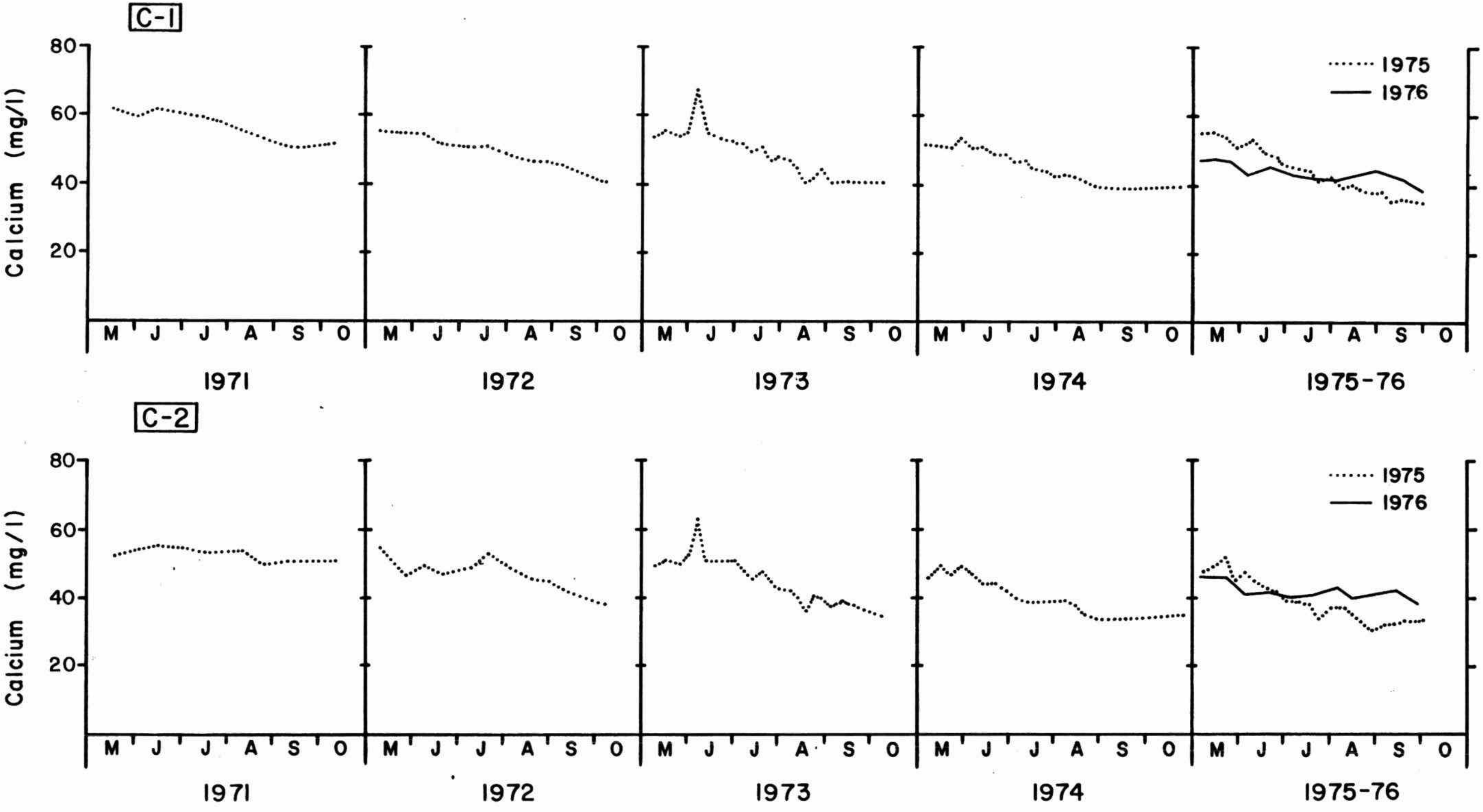


FIG. 7a: Calcium concentrations (mg/l) in Chemung Lake at stations C-1 and C-2 from May to October, 1971 to 1976.

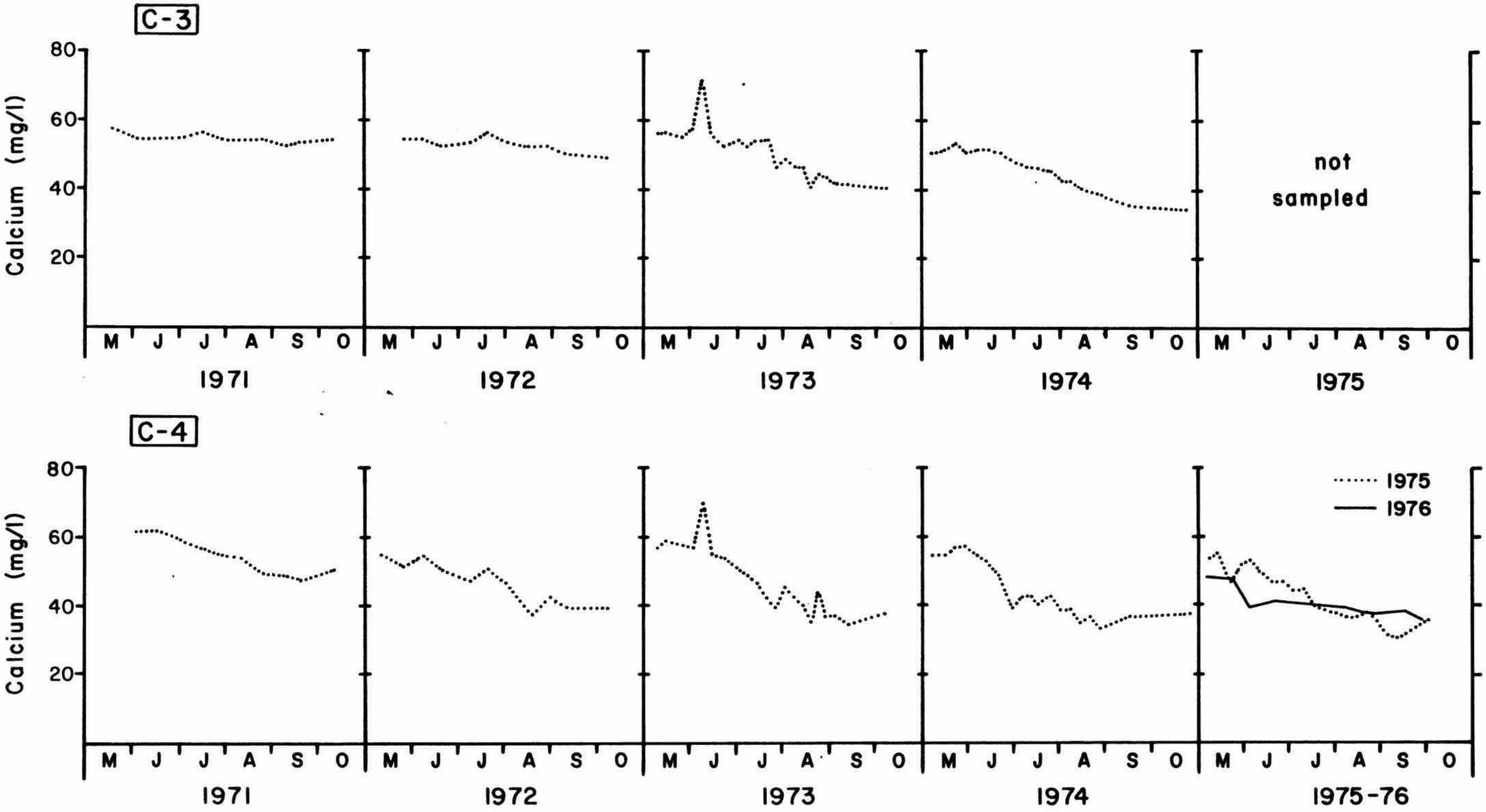


FIG. 7b: Calcium concentrations (mg/l) in Chemung Lake at stations C-3 and C-4 from May to Oct., 1971 to 1976.

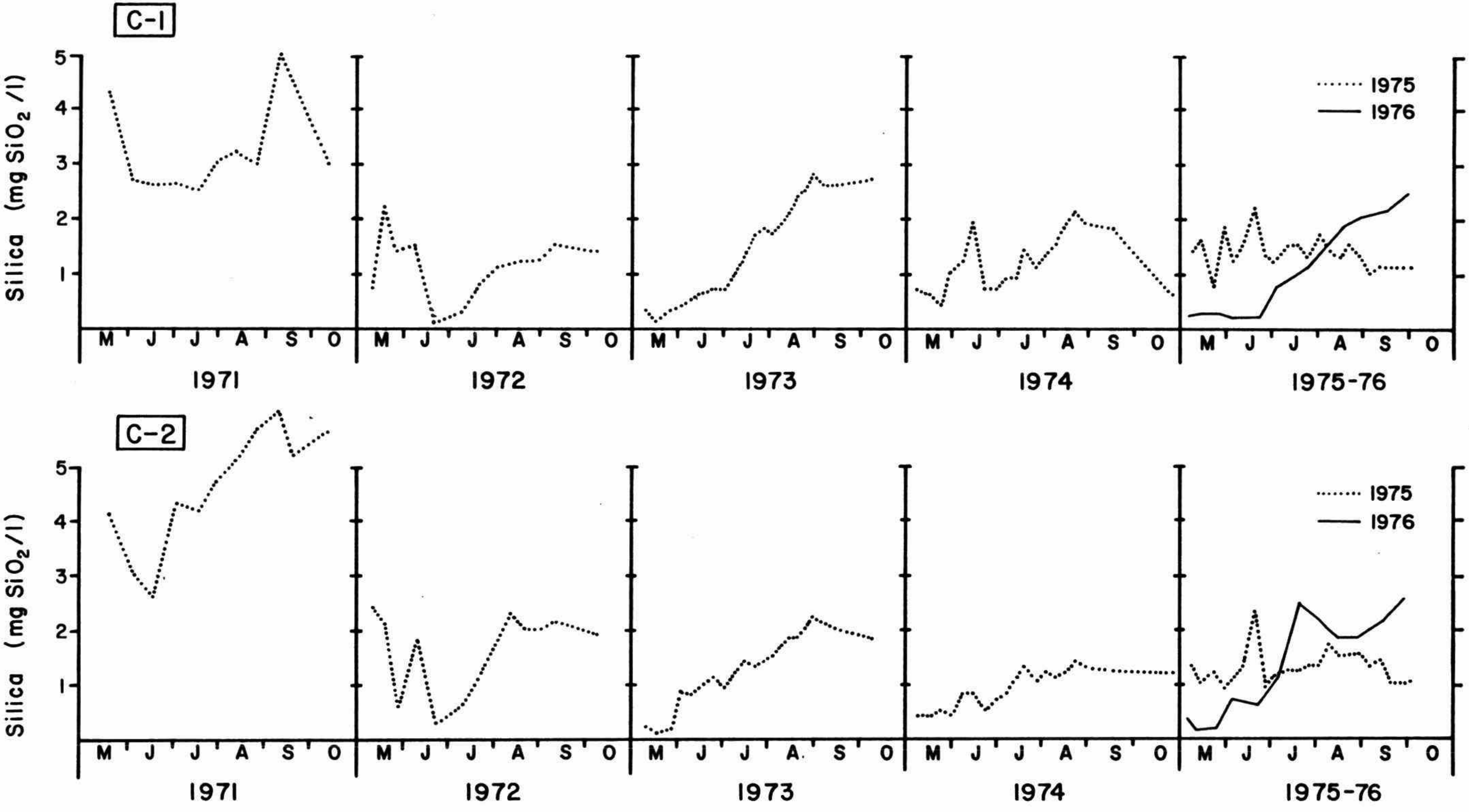


FIG. 8a: Silica concentrations (mg SiO_2/l) in Chemung Lake at C-1 and C-2 from May to October, 1971 to 1976.

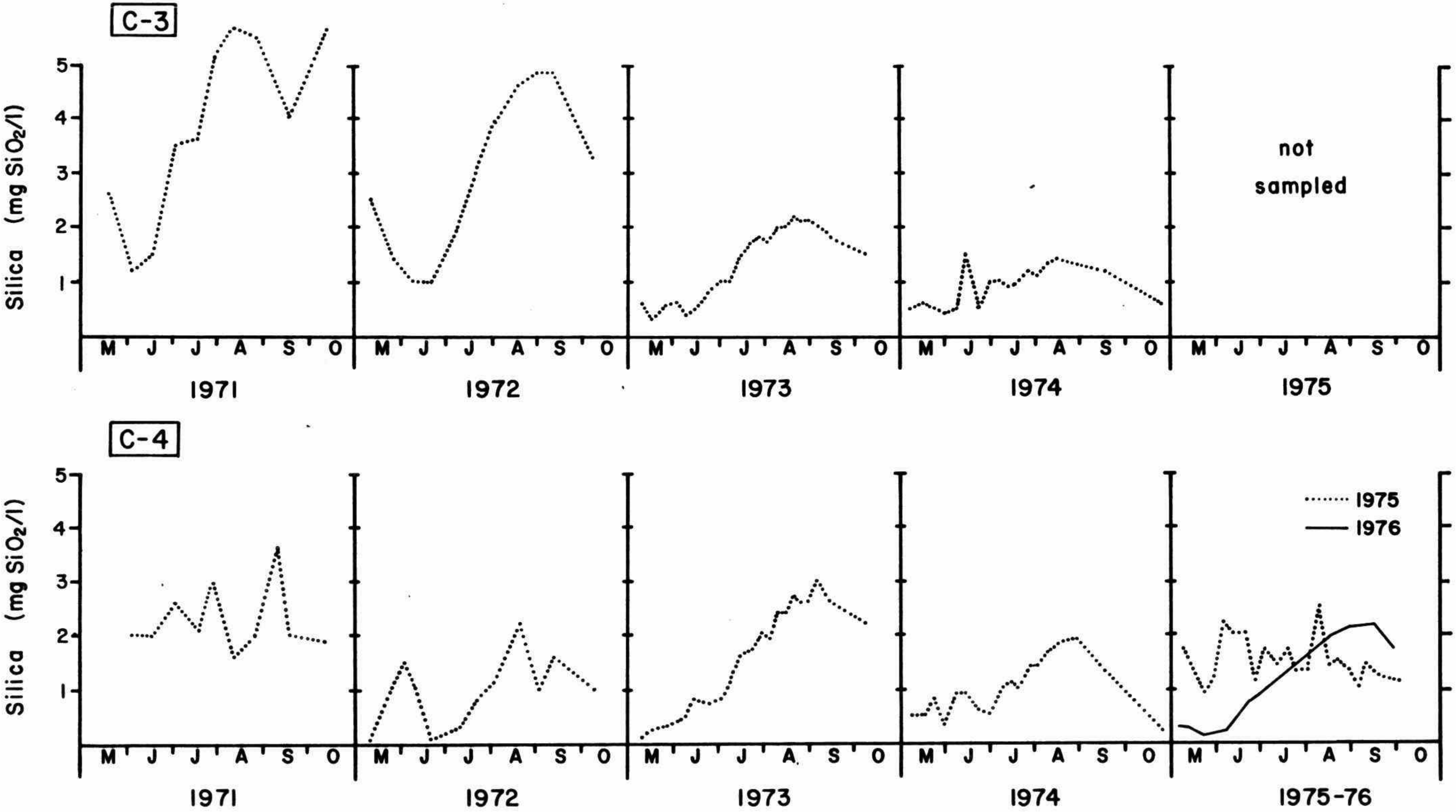


FIG.8b: Silica concentrations (mg SiO_2/l) in Chemung Lake at C-3 and C-4 from May to October, 1971 to 1976.

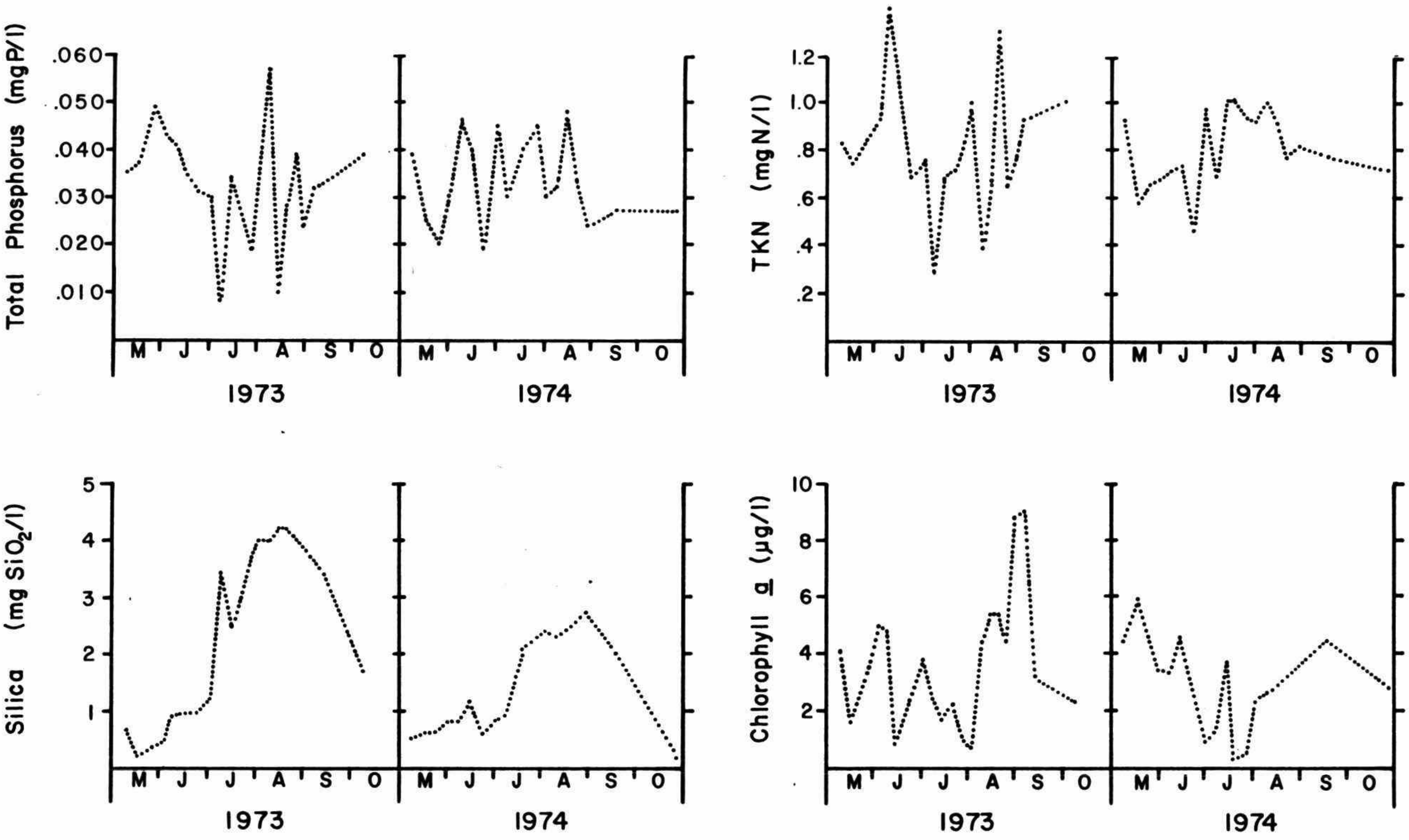


FIG. 9: Total phosphorus (mgP/l), total kjeldahl nitrogen (mgN/l), silica (mg SiO_2/l), and chlorophyll a (µg/l) concentrations in Chemung Lake at station C-5 in 1973 and 1974.

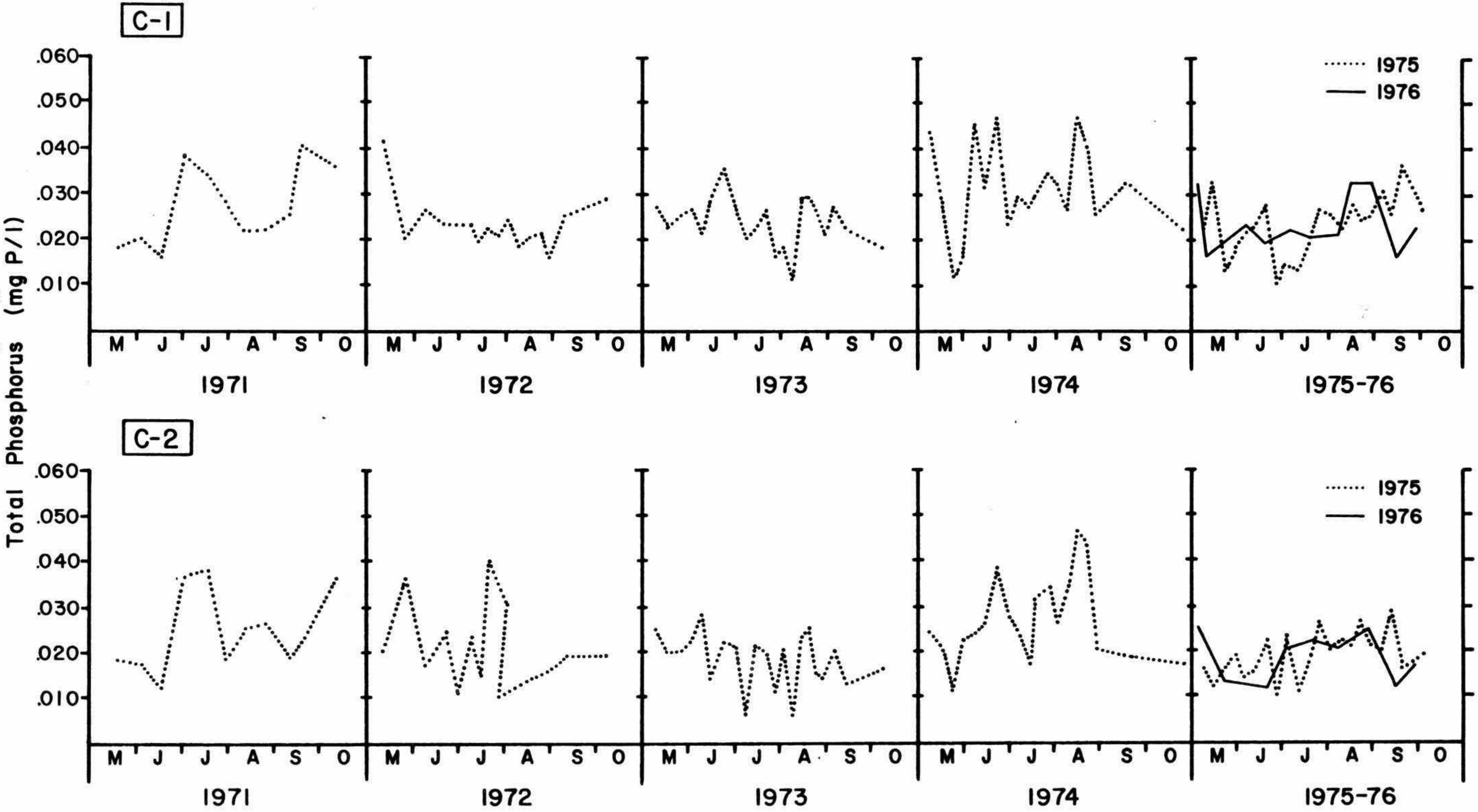


FIG. 10a: Total phosphorus concentrations (mg P/l) in Chemung Lake at C-1 and C-2 from May to October, 1971 to 1976.

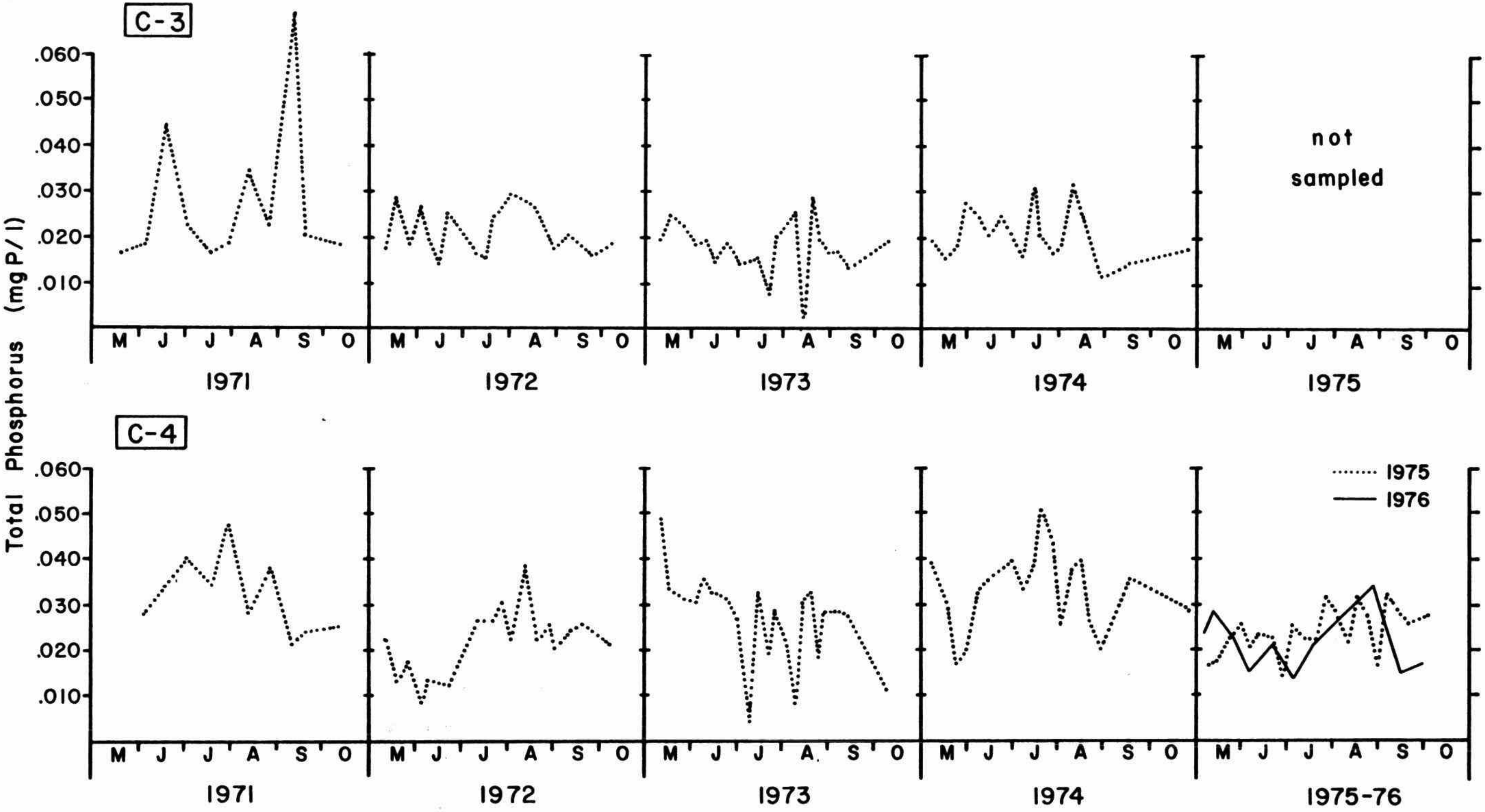


FIG. 10b: Total phosphorus concentrations (mg P/l) in Chemung Lake at C-3 and C-4 from May to October, 1971 to 1976.

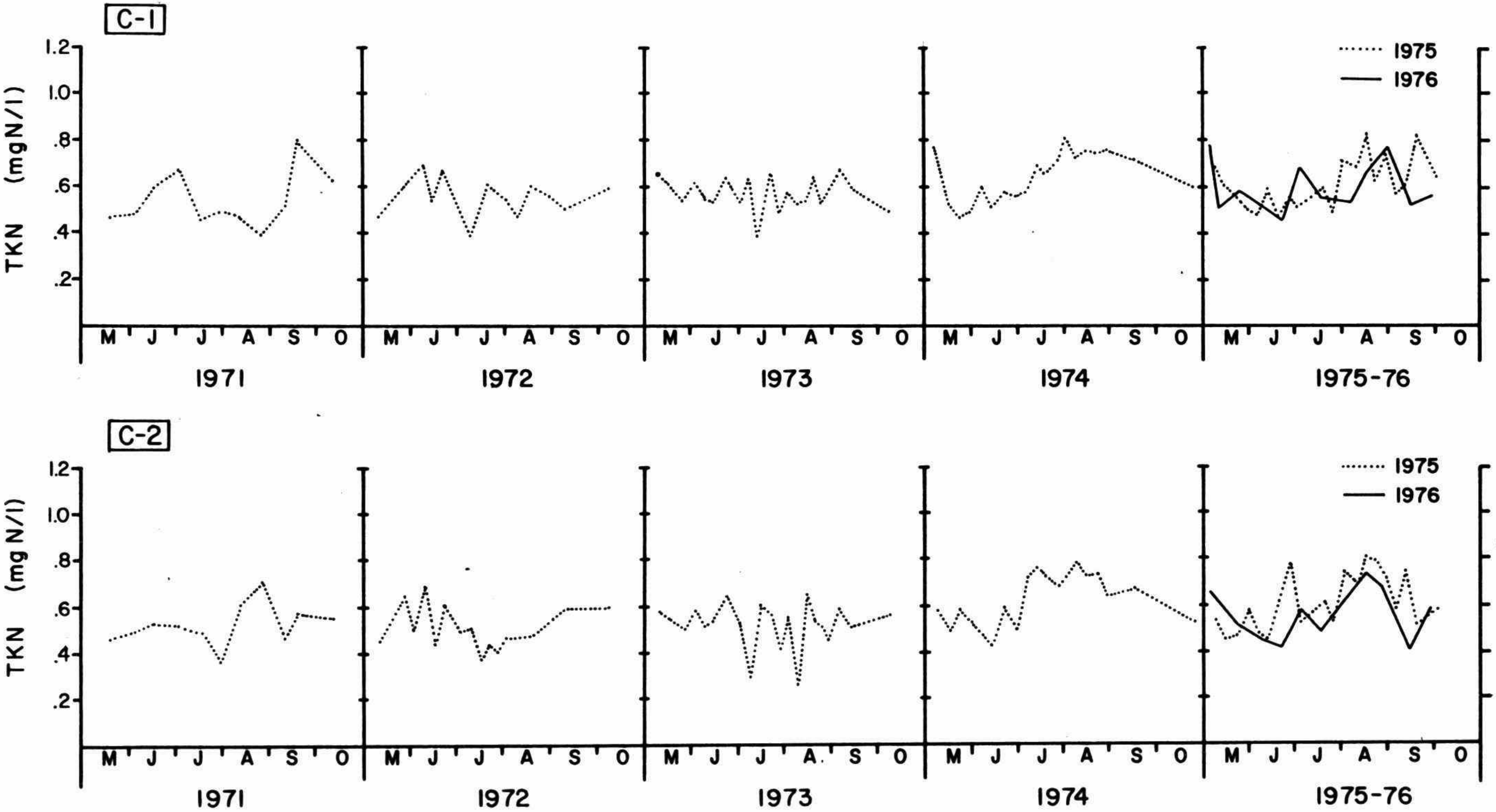


FIG. 11a: Total kjeldahl nitrogen (mgN/l) in Chemung Lake at stations C-1 and C-2 from May to October, 1971 to 1976.

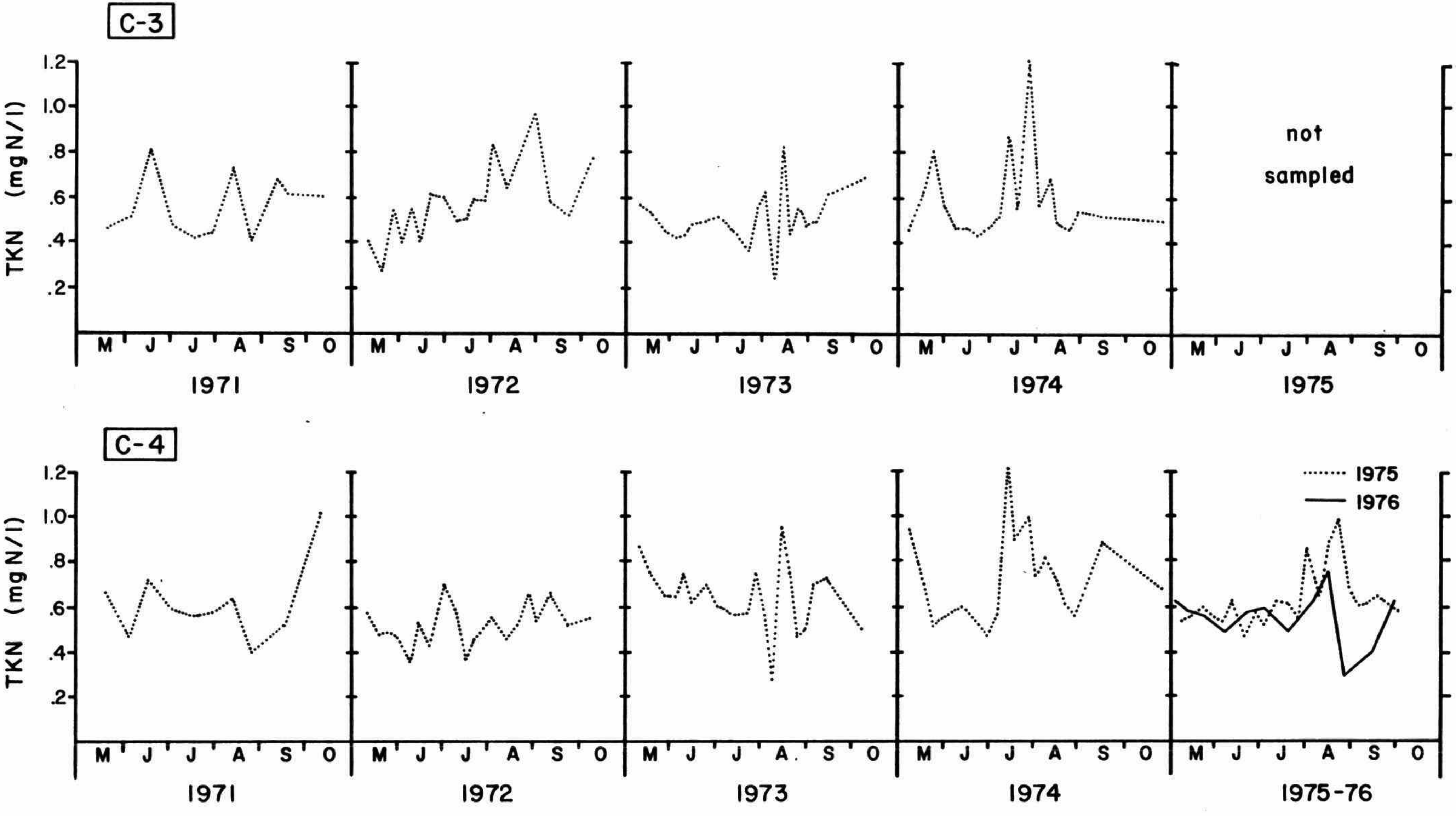


FIG. 11b: Total kjeldahl nitrogen (mgN/l) in Chemung Lake at stations C-3 and C-4 from May to October, 1971 to 1976.

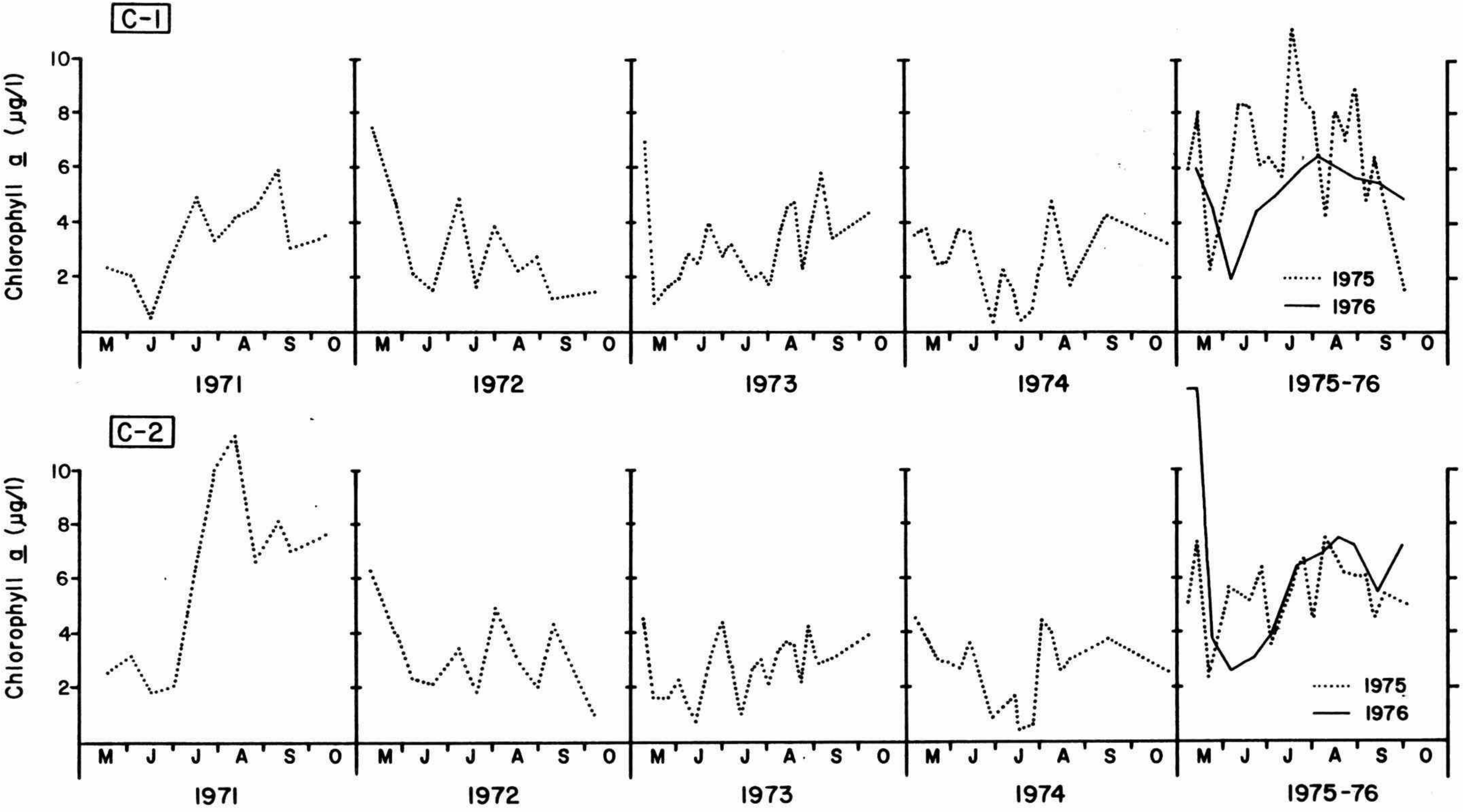


FIG. 12a: Chlorophyll a levels (µg/l) in Chemung Lake at stations C-1 and C-2 from May to October, 1971 to 1976.

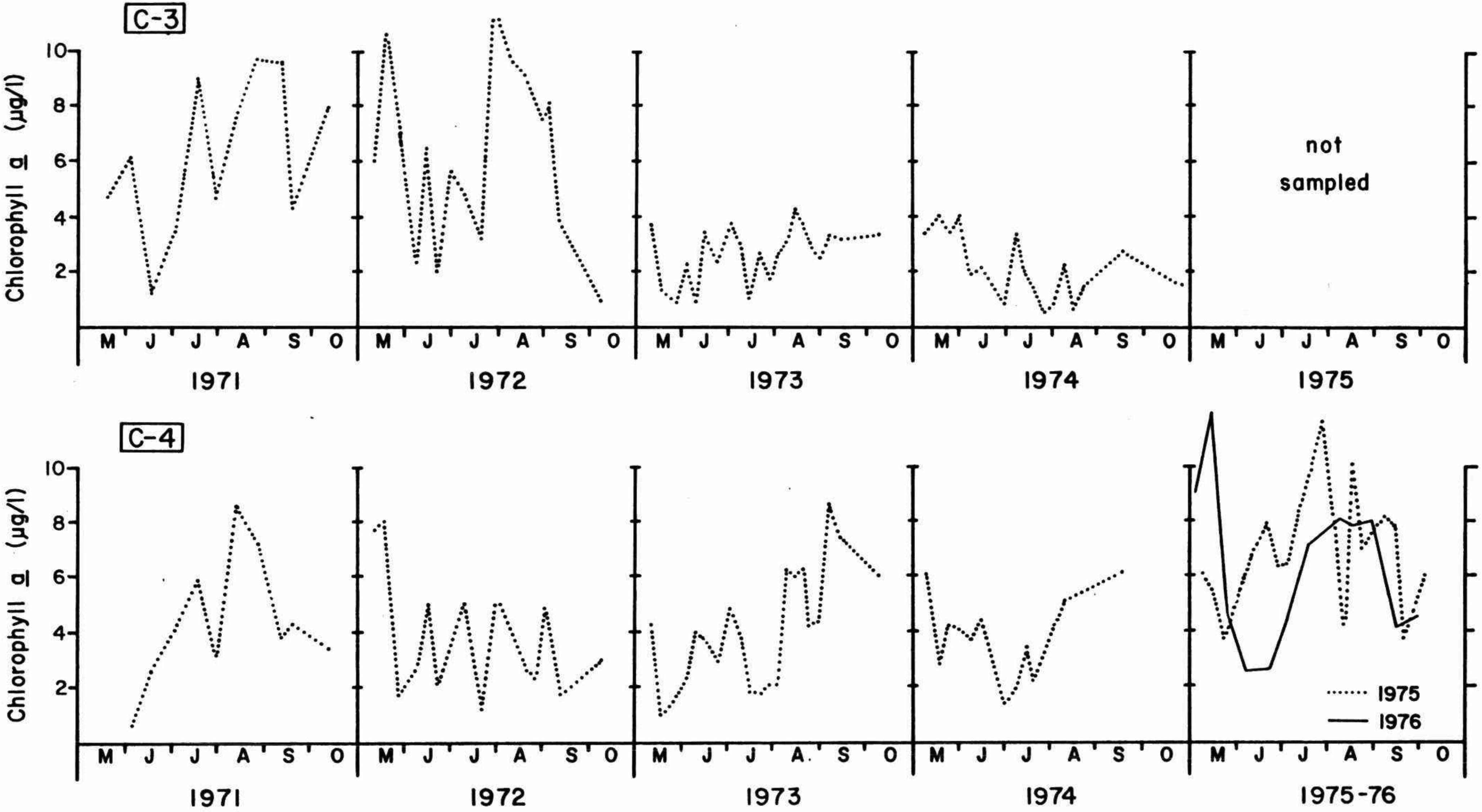


FIG. 12b: Chlorophyll a levels (µg/l) in Chemung Lake at stations C-3 and C-4 from May to October, 1971 to 1976.

CHAPTER 4

PHYTOPLANKTON OF CHEMUNG LAKE

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Figure 2. Phytoplankton stocks and composition at (a) C-2 and (b) C-4 in Chemung Lake in 1975.

Figure 3. Phytoplankton stocks and composition at (a) C-2 and (b) C-4 in Chemung Lake in 1976.

INTRODUCTION

Many workers have observed an antagonistic relationship between aquatic macrophytes and phytoplankton (Hasler and Jones, 1949; Goulder, 1969; Embody, 1929; Bennett, 1942; Wiebe, 1934; Fitzgerald, 1968, 1969a, 1969b). The following possible explanations have resulted: 1) allelopathy - inhibition of the phytoplankton by secretion of a substance produced by the macrophyte, 2) competition for nutrients, 3) competition for light, and 4) dissimilar edaphic requirements. If the phytoplankton are being inhibited by the macrophytes, then removal of aquatic macrophytes by harvesting could potentially result in increased phytoplankton biomass. However, if the two groups of plants do not coexist because of dissimilar edaphic requirements or the macrophytes can out-compete the phytoplankton for nutrients which are mainly concentrated in the sediments, then removal of the macrophytes may not necessarily result in increased phytoplankton biomass. Neel, Peterson and Smith (1973) observed denser phytoplankton concentrations in the first year following harvest. It is, therefore, important to observe phytoplankton concentrations when assessing the effects of harvesting. This report describes phytoplankton populations in Chemung Lake before, during and after harvesting the aquatic macrophytes.

METHODS

Phytoplankton samples were collected as composite water samples through the euphotic zone, the depth of which was determined as being twice the depth of the Secchi disc visibility. An average of twenty samples per station were obtained for the ice-free period during 1972, 1973 and 1975 while only ten samples per station were obtained during 1976. The samples were preserved immediately after collection with Lugol's iodine and identification and enumeration were carried out by inverted microscope after concentration by sedimentation. The phytoplankton biomass was expressed as A.S.U./ml in 1972, 1973 and 1975 and expressed as mm^3/l in 1976. The latter can be converted to A.S.U./ml for comparative purposes using the procedure outlined by Nicholls (unpublished manuscript).

Station 2, station 1 and station 4 were selected as sites for sample collection. The location, depth and weed abundance are described in Table 2 and figure 1 of Chapter 3. However, it is sufficient to recall that Station 2 was located in northern Chemung and is sparsely weeded but Stations 1 and 4 are located in southern Chemung with only Station 4 located in a densely weeded area. Station 4 was situated within the harvested area of southern Chemung each year harvesting was conducted but Stations 1 and 2 were not situated in a harvested area in any year. Approximately 260 to 300 ha were harvested in southern Chemung during 1973, 1974 and 1975 but 95 ha were harvested in southern Chemung and 52 ha were harvested in northern Chemung during 1976.

RESULTS

Figures 1, 2 and 3 illustrate the phytoplankton biomass and percent composition at stations 2 and 4 during 1972, 1975 and 1976. The phytoplankton composition was similar at both stations for all three years. The general seasonal trend is typical of many lakes in southern Ontario. Bacillariophyceae and Chrysophyceae were dominant during the spring whereas Cyanophyceae were dominant during the summer. This successional pattern may be a result of increasing temperatures throughout the season because Cyanophyceae favour warmer temperatures (Wetzel, 1975, pg. 305). The Cyanophyceae became dominant earlier in 1975 because of the earlier warming of the lake water. The average May surface water temperature for Station 2 was 15.7°C for 1972, 17.9°C for 1975 and 10.7°C for 1976.

The common genera present in Chemung Lake are listed in Table 1. Aphanothece, Chroococcus and Cyclotella are normally present in non-eutrophic lakes whereas Melosira, Fragilaria, Stephanodiscus and Anabaena are present in eutrophic lakes. The Chrysophyceae comprised approximately 15% by volume of the total phytoplankton biomass which is indicative of non-eutrophic conditions (MOE, 1976).

Table 2 presents the average phytoplankton biomass for stations 1, 2 and 4 for 1972, 1973, 1975 and 1976. Station 4 had higher concentrations compared to the other stations in 1972 and 1973 but similar concentrations in 1975 and 1976. All stations had lower concentrations in 1976 than preceding years. The phytoplankton volumes as well as A.S.U./ml were measured at Station 2 in 1972 and 1976 and were calculated to be 2.5 mm^3/l in 1972 and 1.9 mm^3/l in 1976. Thus, the decrease in A.S.U./ml in 1976 is believed to be valid, rather than being an error in conversion from mm^3/l to A.S.U./ml.

TABLE 1: Common Phytoplankton Species of Chemung Lake.

Cyanophyceae	Bacillariophyceae	Chrysophyceae	Cryptophyceae
Aphanothece	Synedra	Synura	Cryptomonas
Chroococcus	Melosira	Dinobryon	Rhodomonas
Gomphosphaeria	Fragilaria	Mallomonas	
Aphanocapsa	Stephanodiscus		
Anabaena	Asterionella		
	Cyclotella		

TABLE 2. Average Phytoplankton Biomass (A.S.U./ml)

	Station 2 (North)	Station 1 (South)	Station 4 (South)
1972	2950	2400	4700
1973	2350	2900	3600
1975	2950	3700	3050
1976	1750	2100	1750

DISCUSSION

Several comparisons can be made to illustrate what effects, if any, the harvesting of aquatic plants (predominantly in the southern basin) has had on the phytoplankton. The phytoplankton at station 2 (unweeded) was less dense in 1972 and 1973 but similar to station 4 (weeded) in 1975 and 1976. Station 2 (unweeded, N. basin) and station 1 (unweeded, S. basin) had similar densities in all years. It can, therefore, be presumed that the higher densities of phytoplankton at station 4 (weeded, S. basin) are not because station 4 is situated in the south basin. The presence of *Euglena* in the phytoplankton at Station 4 reveals that the increased densities could possibly be due to increased available substrate area, higher organic content, higher nitrate concentrations or higher temperatures within the weeded areas (Munawar, 1972) and many of the algae at Station 4 are more likely not true phytoplankton but metaphyton (Wetzel, 1975, pg. 390). The decrease in densities at station 4 in 1975 to densities similar to the total lake indicates that harvesting was reducing the area suitable for metaphyton or increasing mixing within the lake.

The decrease in phytoplankton densities in the whole lake during 1976 is difficult to account for. Climatic conditions can affect phytoplankton biomass as was evident in the early dominance in Cyanophyceae during 1975. The mean seasonal temperature at station 2 during 1976 was 18.4°C compared to 20.5°C during 1975 and 19.9°C during 1972, indicating that 1976 was cooler than 1975 and 1972. Low concentrations of phytoplankton may have been observed in 1976 due to the cool and cloudy summer period. However, it is also possible that the harvesting during the preceding three years was finally having an effect.

Table 3 presents the phytoplankton biomass and chlorophyll *a* concentrations and Secchi disc depths for Stations 2, 1 and 4 for 1971 to 1976. The phytoplankton biomass has decreased in 1976 compared to previous years. However, the chlorophyll *a* concentration has increased at all stations during 1975 and 1976. These increases have been accompanied by decreases in the Secchi disc depths. Although it is difficult to interpret such observations, it appears likely that the increase in chlorophyll *a* and decrease in secchi depth are not a result of increased concentrations of viable phytoplankton but more likely a result of increased turbidity and pigment concentration from disturbed sediments and macrophyte beds. Increased pheopigment concentrations as a result of such disturbance would increase chlorophyll and decrease the secchi depth but would not affect phytoplankton biomass, unless the turbidity increased sufficiently to reduce primary production. To test the above hypothesis, pheopigments were measured in 1977. The measurements suggest that approximately 54% of the total chlorophyll a concentrations were pheopigments. Therefore, a large portion of the turbidity in Chemung can be attributed to pheopigments during 1977 and probably in previous years. Harvesting intensity in Chemung was reduced in 1977 compared to previous years and turbidity in Chemung during 1977 was similar to previous years as illustrated by the mean Secchi disc depth of 1.5 m for the three stations. One must conclude that if harvesting was having an effect on water clarity, it was masked by more dominant influences such as resuspension of particulate matter by wind action.

CONCLUSIONS

Species composition of the phytoplankton of Chemung Lake is similar at all stations from 1972 to 1976 and is generally characteristic of mesotrophic lakes. The biomass of phytoplankton was higher at the weeded station during preharvest years. The harvesting of aquatic macrophytes has coincided with a reduction in the biomass of phytoplankton at the weeded station to concentrations similar to the remainder of the lake. The phytoplankton biomass also decreased throughout the lake during 1976 to values smaller than previously observed. It is uncertain whether this is a weather effect or a result of the harvesting. The chlorophyll a concentration increased and the secchi depth decreased in 1975 and 1976 compared to previous years. These observations are probably not a result of increased phytoplankton biomass but rather a result of increased turbidity and pheopigment concentration resulting from the harvesting operation or wind mixing of the lake. The 1977 data would tend to suggest that wind action was the dominant factor influencing water clarity.

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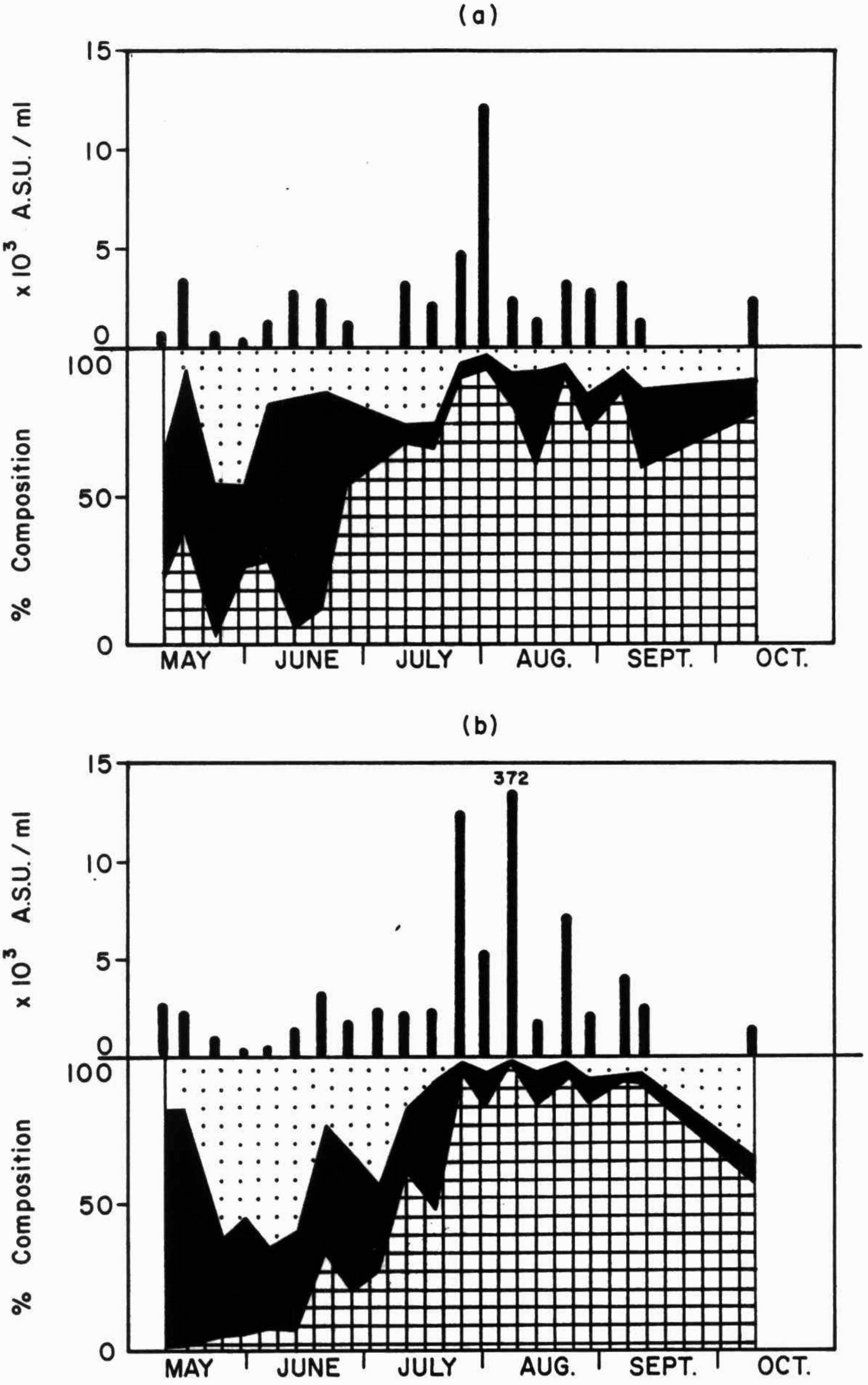

FIG. I. Phytoplankton stocks and composition at (a) C-2 and (b) C-4 in Chemung Lake in 1972.

(⊞ Cyanophyceae, ■ Bacillariophyceae, ⁙ Others)

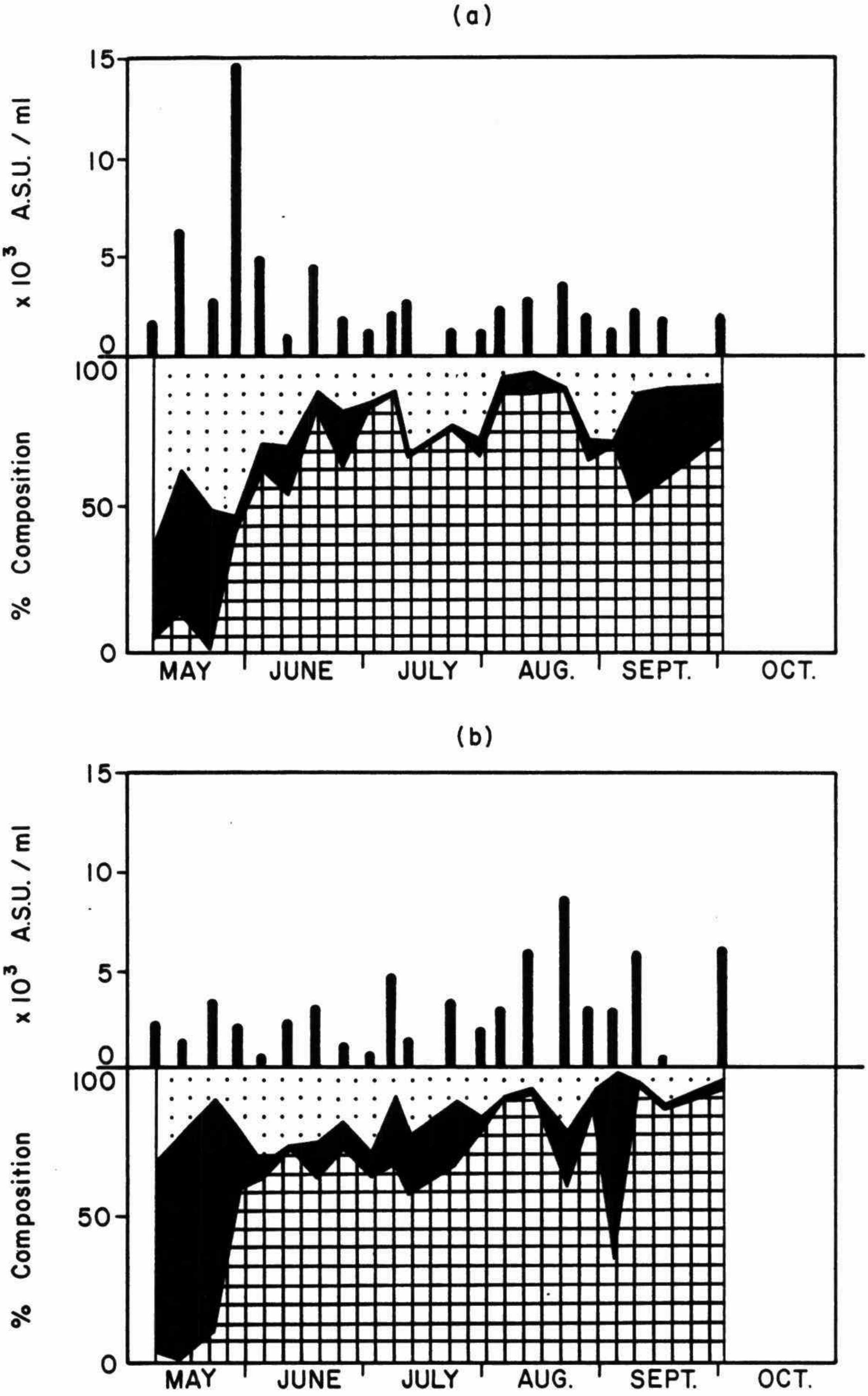

FIG. 2. Phytoplankton stocks and composition at (a) C-2 and (b) C-4 in Chemung Lake in 1975.
(▦ Cyanophyceae, ■ Bacillariophyceae, ⁚ Others)

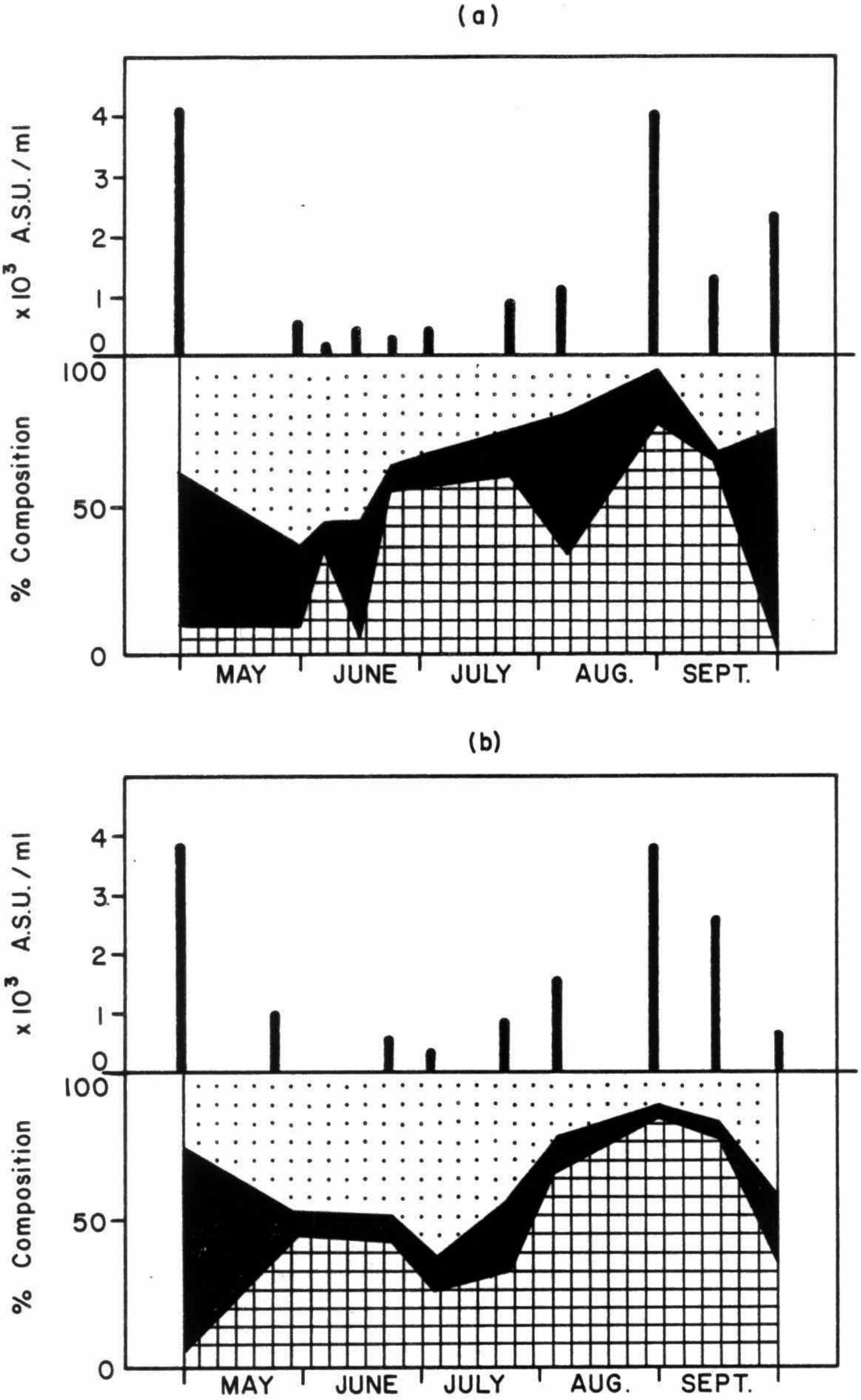

FIG. 3. Phytoplankton stocks and composition at (a) C-2 and (b) C-4 in Chemung Lake in 1976.

(▦ Cyanophyceae, ■ Bacillariophyceae, ⁙ Others)

CHAPTER 5

THE ZOOPLANKTON OF CHEMUNG LAKE

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(b) Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-3 and (b) C-4 in 1971.

2(a) Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-1 and (b) C-2 in 1972.

(b) Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-3 and (b) C-4 in 1972.

3(a) Percentage composition of the cladocerans for the four major species found in Chemung Lake at C-1 in 1971, 1972 and 1974.

(b) Percentage composition of the cladocerans for the four major species found in Chemung Lake at C-2 in 1971, 1972 and 1974.

(c) Percentage composition of the cladocerans for the four major species found in Chemung Lake at C-4 in 1971, 1972 and 1974.

4. Species composition and relative abundance of crustaceans in Chemung Lake at C-1 in 1974.

5. Species composition and relative abundance of crustaceans in Chemung Lake at C-2 in 1974.

6. Species composition and relative abundance of crustations in Chemung Lake at C-4 in 1974.

7. The relationship between crustacean abundance (individuals/liter) and total phytoplankton (mm^3/l in the Kawartha Lakes in 1972, based on summer mean values.

INTRODUCTION

This chapter summarizes data collected from Chemung Lake in 1971, 1972 and 1974 regarding zooplankton species composition and abundance. Observations during the first two years were used to determine the natural occurrence of species and to predict seasonal variations. Samples collected in 1974 were analyzed to determine if mechanical weed harvesting (initiated in 1973) had altered the natural zooplankton community. An attempt was made to predict the long term consequences of lake restoration techniques on zooplankton, using data collected from other lakes in the Kawartha-Trent system.

METHODS

Field Methods

During the summer of 1971, zooplankton samples were collected from four selected stations (corresponding to the water quality sampling stations - Chapter 3) a total of ten times. In 1972, and 1974, the sampling program was intensified to once a week to cover the ice-free period from May until October. Winter samples were collected once in February, 1972. Collections were obtained by means of a vertical net haul from one meter off the bottom using a Wisconsin-type plankton net (with a 12 cm upper-ring diameter and #20 mesh size (76μ). Samples were preserved in a 4% formaldehyde solution. Station C-3 was not sampled in 1974 due to the nature of the communities found in 1971-72. Stations C-1 and C-4 were harvested while C-2 served as a control station.

Laboratory Methods

Each zooplankton sample was emptied into a petri dish and examined using a dissecting microscope with a 40X maximum magnification. In some instances (due to excessive plankton numbers) it was necessary to sub-sample. A diluted sample was shaken vigorously to disperse the organisms throughout the sample. While the sample was being mixed, 10 ml aliquots were taken with a large-bore 10 ml pipette and drained into a petri dish. Zooplankton abundance was expressed as the number of organisms under a unit area (1 sq. cm.) of lake surface and as ind./liter. Nauplii (immature copepods) and cladoceran juveniles were included. To facilitate identification, a compound microscope proved useful for clarifying the more detailed taxonomic features. Taxonomic references consulted included Edmondson (1959), Brooks (1957), Czaika and Robertson (1968), and Bradlova _et al_. (1972).

RESULTS

Species Composition and Abundance

Table 1 provides a breakdown of the zooplankton species identified in Chemung Lake during the study period. Thirty-four species of crustacea were found. There were three calanoid copepods, *Diaptomus oregonensis*, *Diaptomus minutus*, and *Epischura lacustris*, five species of cyclopoid copepods and one species of harpacticoida. On several occasions, specimens of the parasitic copepod *Ergasilus sp*. were observed. The remaining twenty-four species were of the order Cladocera. Of these, fifteen could be considered as rare, and in several cases this was limited to once during the study period.

The most frequently encountered species were *Cyclops bicuspidatus thomasi* (occurring in significant numbers in the spring and fall, but absent from the summer populations), *Tropocyclops prasinus mexicanus* (the numerically dominate summer copepod), *Mesocyclops edax* (also a prominent summer species), *Cyclops vernalis* (sporatic occurrence), *Daphnia galeata mendotae*, *Daphnia retrocurva*, *Eubosmina coregoni*, and *Chydrous sphaericus*. These last four exhibited extreme body distortions in the summer months. Also having a regular occurrence were *Diaphanosoma leuchtenbergianum* and *Ceriodaphnia lacustris*. Table 2 indicates the percentage composition of the species. Calanoids rarely exceeded 10% of the total number of organisms present at any one time. At station C-1, the greatest percentage of species present were Cladocerans. Stations C-2 and C-4 had roughly equivalent percentages of cyclopoids and cladocerans in 1971 and 1972, and slightly elevated percentages of cladocerans in 1974. The distribution of species at C-3 in 1971 and 1972 was dominated by cyclopoids. The greatest numbers of organisms were found at C-1 (Table 2). Relative abundance and species composition was similar over the three years. Figures 1 and 4 illustrate the seasonal variation in community structure and size in Chemung Lake in 1971, 1972 and 1974.

In the winter of 1972 stations C-1 and C-4 were sampled for comparison purposes. At C-1, *D. oregonensis*, the major calanoid copepod found in the summer in insignificant numbers, dominated the winter plankton community (Table 3). Also present in order of importance were *C. b. thomasi*, *T.p. mexicanus*, *E. coregoni*, *Daphnia pulex*, and *C. sphaericus*. The average

Table 1: List of crustacean species found in Chemung Lake and their occurrence at four sampling stations in 1971, 1972 and 1974, (+ species present, · species present but rare, - species absent).

Species	1971				1972				1974		
	C-1	C-2	C-3	C-4	C-1	C-2	C-3	C-4	C-1	C-2	C-4
Copepods:											
Attheyella americana (Herrick)	-	-	-	-	-	-	-	·		-	-
Cyclops bicuspidatus thomasi (S.A.Forbes)	+	+	+	+	+	+	+	+	+	+	+
Cyclops vernalis (Fischer)	+	+	+	+	+	+	+	+	+	+	+
Diaptomus minutus (Lilljeborg)	·	-	·	·	-	-	-	-	+	-	-
Diaptomus oregonensis (Lilljeborg)	+	+	+	+	+	+	+	+	+	+	+
Epischura lacustris (S.A. Forbes)	·	·	+	+	·	·	+	·	-	-	-
Eucyclops agilis (Koch)	-	-	·	-	·	·	·	·	-	-	-
Mesocyclops edax (S.A. Forbes)	+	+	+	+	+	+	+	+	+	+	+
Tropocyclops prasinus mexicanus (Kiefer)	+	+	+	+	+	+	+	+	+	+	+
Ergasilus sp.	-	-	-	-	-	·	·	·	-	-	-
Cladocera:											
Acroperus harpae (Baird)	-	-	-	-	-	·	·	·	-	·	-
Alona affinis (Leydig)	·	-	-	-	-	-	-	-	-	-	-
Alona quadrangularis (O.F. Müller)	-	-	-	-	-	·	-	-	-	-	-
Alona rectangula (Sar)	·	-	-	-	-	-	·	-	-	·	·
Alonella sp.	-	-	-	-	-	-	-	·	-	-	-
Bosmina longirostris (O.F. Müller)	+	+	+	+	+	+	+	+	+	+	+
Ceriodaphnia lacustris (Birge)	·	+	+	+	+	+	+	+	+	+	+
Chydorus sphaericus (O.F. Müller)	+	+	+	+	+	+	+	+	+	+	+
Daphnia galeata mendotae (Birge)	+	+	+	+	+	+	+	+	+	+	+
Daphnia longiremis (Sars)	·	·	·	-	-	-	-	-	-	-	-
Daphnia pulex (Leydig)	+	·	·	+	·	·	+	·	-	-	-
Daphnia retrocurva (Forbes)	+	+	+	+	+	+	+	+	+	+	+
Daphnia rosea (Sars)	-	-	-	·	+	+	+	+	·	-	-
Eubosmina coregoni (Baird)	+	+	+	+	+	+	+	+	+	+	+
Eurycercus lamellatus (O.F. Müller)	-	-	·	-	-	·	-	·	·	-	-
Holopedium gibberum (Zaddach)	-	-	·	·	-	·	·	+	-	-	-
Latona setifera (O.F. Müller)	-	-	-	-	-	-	-	+	-	-	-
Leptodora kindtii (Focke)	·	·	-	·	+	+	·	·	·	·	·
Ophryoxus gracilis (Sars)	-	-	-	-	-	-	·	·	·	-	-
Pleuroxus sp.	-	-	-	-	-	-	-	·	-	·	-
Polyphemus pediculus (Linné)	-	-	-	-	-	·	·	-	-	-	-
Sida crystallina (O.F. Müller)	-	-	-	-	·	·	-	·	·	-	-
Simocephalus serrulatus (Koch)	-	-	-	-	-	·	·	-	-	-	-

Table 2: Percentage composition of species and relative abundance of organisms present in Chemung Lake in 1971, 1972 and 1974.

	C-1	C-2	C-3	C-4
1971				
Nauplii	4.7	9.2	13.0	12.1
Calanoids	0.6	0.7	0.6	1.0
Cyclopoids	13.6	42.8	80.0	33.7
Cladocera	80.9	47.3	6.4	52.7
ind/cm^2	28.4	13.3	13.3	11.8
ind/liter	56	38	27	73
1972				
Nauplii	3.6	6.8	3.7	8.9
Calanoids	6.2	5.8	1.3	7.8
Cyclopoids	27.9	45.6	69.5	41.4
Cladocera	62.3	41.8	25.5	41.9
ind/cm^2	28.9	14.5	9.7	9.0
ind/liter	58	41	17	48
1974				
Nauplii	3.1	4.8	-	3.7
Calanoids	7.5	10.2	-	4.6
Cyclopoids	20.3	33.1	-	33.1
Cladocera	69.1	51.9	-	58.6
ind/cm^2	34.7	14.5	-	14.5
ind/liter	68	48	-	64

number of organisms present was much less than summer averages (5.9 ind/cm^2 or 17 ind/liter. Low water levels, combined with a thick layer of ice at C-4, reduced sampling depth to one meter. No crustaceans were found.

Some of the nutrient data and zooplankton data for Chemung Lake has been summarized in Table 4.

Seasonal Trends

It is well recognized that most planktonic species are cyclic in occurrence, rising to peaks for short periods and then declining. Pennak (1957) emphasizes the importance of distinguishing between seasonal and momentary composition of planktonic communities. Since immature copepods are difficult, if not impossible to identify with certainty, particularly in the early stages, only mature organisms were speciated. However, some general trends were apparent.

Cyclops bicuspidatus thomasi appeared in considerable numbers in the spring and then again in the late fall, but was significantly absent from the summer collections. Andrews (1953) observed similar results during his two year study of Lake Erie, with this species being absent from early summer until early winter. In Wisconsin and Minnesota lakes C. b. thomasi was found to enter a summer diapause as a copepodite larva in the mud (Hutchinson 1967). In Parry Sound, Carter (1972) found it to have a mid-summer maximum and concluded it to be basically a winter and spring species which can become year-round when conditions are suitable.

Mesocyclops edax was a prominant summer species. This large cyclopoid has been observed to show a winter diapause (Hutchinson 1967). This may provide a temporal separation between this species and C. b thomasi.

Tropocyclops prasinus mexicanus was the numerically dominant copepod in the summer, but little is known about its seasonal dynamics to determine if observed trends are typical. Chandler (1940) found it from April to October in the western basin of Lake Erie. In Lake Ontario, it was found to develop later than C. b thomasi (Patalas 1969). Again a temporal separation is probable between species.

Cyclops vernalis occurred sporadically throughout the study period over the entire lake.

Table 3: Percentage composition of the crustacean community in Chemung Lake at C-1, on February 23, 1972.

	Percentage Composition
Calanoids (exclusively D. oregonensis)	57.7
Nauplii	21.4
Cyclopoids	10.2
Cladocera	10.7

Table 4: Chemung Lake summer means for total phosphorus (mg P/l), chlorophyll a (ppb), individuals/cm^2/m, and number of calanoids and cladocerans (expressed as a % of total crustaceans present) in 1971, 1972 and 1974.

	Total P	Chloro a	ind/cm^2/m	% calanoids	% cladocerans
Chemung 1971	.027	5.0	4.9	0.7	46.8
Chemung 1972	.025	4.1	4.1	5.3	42.8
Chemung 1974	.030	2.8	6.0	7.4	59.9

Table 5: Percentage composition of the cladocerans in Chemung Lake in 1971, 1972 and 1974.

	C-1	C-2	C-3	C-4
1971				
Chydorus	43.9	58.5	48.4	47.7
Bosmina	32.0	20.4	18.6	25.8
Daphnia	22.2	18.4	16.9	12.3
Ceriodaphnia	0.1	0.4	2.4	5.2
Others	1.8	2.3	13.7	9.0
1972				
Chydorus	13.8	45.8	55.9	33.9
Bosmina	47.3	25.1	24.9	36.9
Daphnia	35.5	18.4	11.4	11.0
Ceriodaphnia	0.4	0.5	2.4	10.0
Others	3.0	10.2	5.4	8.2
1974				
Chydorus	33.8	39.3	-	32.1
Bosmina	33.4	32.8	-	34.5
Daphnia	29.7	16.0	-	14.2
Ceriodaphnia	0.5	8.8	-	16.1
Others	2.6	3.1	-	3.1

Seasonal composition of the cladocera is illustrated in Figure 2 (a-c) for the four major species, while percentage composition for the years is given in Table 5.

Chydorus sphaericus was a prominent cladoceran in Chemung Lake. Although considerable irregular variations existed at the different stations, there was a general trend for elevated numbers during the summer months, with reduced numbers appearing in the spring and late fall. Patalas (1969) found it from July to September in Lake Ontario.

Bosmina spp. concentrations in 1971 accounted for a significant part of the cladocerans present in early spring and in the fall, but mid-summer concentrations were negligible. Although similar patterns were observed in 1972 and 1974, maxima and minima were less extreme, and significant numbers persisted throughout the summer months. Patalas (1969) found insignificant concentrations for E. coregoni from July to September in Lake Ontario. B. longirostris and E. coregoni were found in Chemung Lake.

Daphnia galeata mendotae generally had a late spring - early summer maxima followed by irregular oscillations which culminated in a late summer second maxima. Hutchinson (1967) noted similar trends for this species in Lake Mendota and several other lakes.

Daphnia retrocurva generally had one or two striking summer maxima which is characteristic of this species and somewhat similar to Brooks' (1957) generalization of spring and early fall maxima for this species. This species was prominent at times when D. g. mendotae were less abundant

DISCUSSION

Having examined the cyclic occurrence of the major species it is interesting to examine the zooplankton community as a whole. The great majority of limnetic communities are characterized at any one time by one numerically dominant species of copepod and cladoceran. From a study of limnetic collections throughout the world, Pennak (1957) summarizes the number of species that occur simultaneously. His results yielded a copepod mean of 2.7 and a cladoceran mean of 2.8. Chemung Lake on the other hand is remarkably rich in copepod and cladoceran species. Means of 4.3 and 5.7 for copepod and cladoceran species respectively are almost twice that observed by Pennak, and numerical dominance was often shared by more than one species of each.

One may speculate for the reasons behind this unusual occurrence of such a large number of species. Pennak considered only limnetic populations, those occurring in open water devoid of the influence of rooted aquatics and shoreline shallows. The relative shallow depth of Chemung Lake and heavy macrophyte growth result in the inclusions of many littoral species, that although occurring in insignificant numbers, have a profound affect on this interpretation. Several authors have noted that distinct food preferences are exhibited by different species. Simocephalus is a bottom substrate feeder, Cyclops can be a predaceous species and even in the filter-feeders, there are size-specific mechanisms involved. Thus interspecific competition could be avoided or reduced by different food preference. Reed (1964) in his study of sub-arctic lakes states that "the physical environment is sufficiently benign to permit the existence of several species, none of which is adapted well enough to utilize the resources of the environment to the exclusion of the others".

Several species displayed a form of cyclomorphisis in which extreme phenotypes were produced. In D. retrocurva and D. g. mendotae this manifested itself in the development of the anterior part of the head to form an appreciable helmet. In E. coregoni the antennules became very elongate and the mucro (homologous with the shell spine in Daphnia) disappeared. These body changes relate to favourable growth conditions; warm water (20-25^{o}C), turbulence, ample nutrition and moderate light intensities. Lower numbers of crustaceans and a lack of extreme polymorphisms characterized the winter community, coinciding with less favourable environmental conditions (low water temperature, reduced food supply).

The interpretation of changes in relative abundance and species composition of a zooplankton community is often difficult because of the great natural variation that exists. This problem is further compounded when one attempts to characterize these communities relative to the effects of natural and/or cultural eutrophication, or relate a specific community structure to a trophic level. When Chemung Lake results were compared to the plankton communities in the other Kawartha Lakes, they reassembled the intermediate category described in Chapter 3 of The Kawartha Lakes Water Management Study - Water Quality Assessment (1972-1976).

While attempting to categorize Chemung Lake relative to its trophic status, certain elements of the zooplankton community serve as indicators of enrichment. E. coregoni is typical of rather shallow, warm, eutrophic lakes (Patalas 1971). C. sphaericus, a significant member of the summer population, also suggests that Chemung is well along on the trophic scale. This is a case where increasing eutrophication has led to the proliferation of blue-green algae, unsuitable to most aquatic herbivores, but providing both food and substrate for C. sphaericus. Changing trophic levels will undoubtedly result in more structural shifts in the zooplankton community.

An objective interpretation of the available data from Chemung Lake indicates that high numbers of individual zooplankters existed in the spring, followed by a mid-summer decline, and a smaller peak in late summer. The explosive spring pulse in zooplankton abundance was likely a response to the rise in temperature which increases the rate of melting and brood production, and to increased food supply (phytoplankton) which increases the number of eggs per brood. The mid-summer decline in crustacean numbers could have resulted after the heat content of the lake surpassed its optimum level. Similar (temperature related) declines from very high to medium levels have frequently been observed in many meso and eutrophic lakes in Poland and Lake Erie (Patalas - 1966, 1972). When chlorophyll a levels in Chemung Lake were plotted against numbers of zooplankton, a definitive relationship did not exist. Zooplankton populations can exhibit a lag response whereby numbers increase after optimum phytoplankton production. Also the fact that maximum and minimum chlorophyll a levels were not significantly different throughout the lake (ranging between 3.2 and 6.1 µg/l) could explain this apparent inconsistency. When this relationship was plotted using data from all the Kawartha Lakes (which had a wide range of chlorophyll values) there was a significant correlation ($r = 0.79$) (Kawartha Lakes Water Management Study, Water Quality Assessment, 1972-1976). However, a better correlation ($r = 0.91$) was derived when total phytoplankton biomass was used (Fig. 5), indicating that zooplankton numbers are definitely dependent on the amount of phytoplankton available. Knowing that phytoplankton assimilation and reproduction is governed by the fertility of the surrounding water it was anticipated that algal levels, as well as zooplankton abundance would be related to nutrient concentrations in the water. Several authors have observed a direct linear relationship between chlorophyll a concentrations and total phosphorus concentrations in the photic zone (Sakamoto 1966, Dillon & Rigler 1974). Again a significant relationship only existed when a wide range of values, representing all the Kawartha Lakes were used, yielding an r value of 0.79. Zooplankton numbers and total phosphorus concentrations in the photic zone were also highly related in the Kawartha Lakes, with r = 0.94.

Having developed these relationships, it is apparent that algal levels, nutrient concentrations in the surface waters and zooplankton abundance are all highly correlated. Vollenweider (1969) indicates that the concentration of phosphorus in lakes seems to be largely determined by the supply, and is modified by other factors such as water replenishment, degree of dilution, etc. The small volume of Chemung Lake, and the limited flow, would tend to indicate that the latter are of little importance in determining lake concentrations. Chemung Lake has produced a nutrient-rich environment, that supports luxurient growths of aquatic macrophytes. These macrophytes have the capability of acting as biological filters to remove large quantities of nutrients from circulation in the water column. Wile and McCombie (1972) in a study of Southern Ontario impoundments, found that where growths of macrophytes were sparse or restricted to comparatively small littoral zones, the standing crops of phytoplankton were heavy during the summer and where macrophyte growth was heavy, phytoplankton growth was reduced perhaps because the macrophytes were capable of absorbing more nutrients earlier in the season. Thus, it would appear that zooplankton abundance in a heavily weeded lake such as Chemung Lake is indirectly related to the competitive advantage the macrophytes exert on the phytoplankton community.

In 1972, it was estimated that over 2000 kg of phosphorus was tied up in macrophyte tissues in southern Chemung Lake. The possibility therefore exists, that mechanical removal of large quantities of macrophytes could alter phosphorus supply to phytoplankton and hence alter zooplankton abundance, and species composition. Two years of harvesting in lower Chemung Lake has not significantly altered this balance, although investigations should continue to determine if repetitive harvesting will have any long term effects on the zooplankton community in Chemung Lake.

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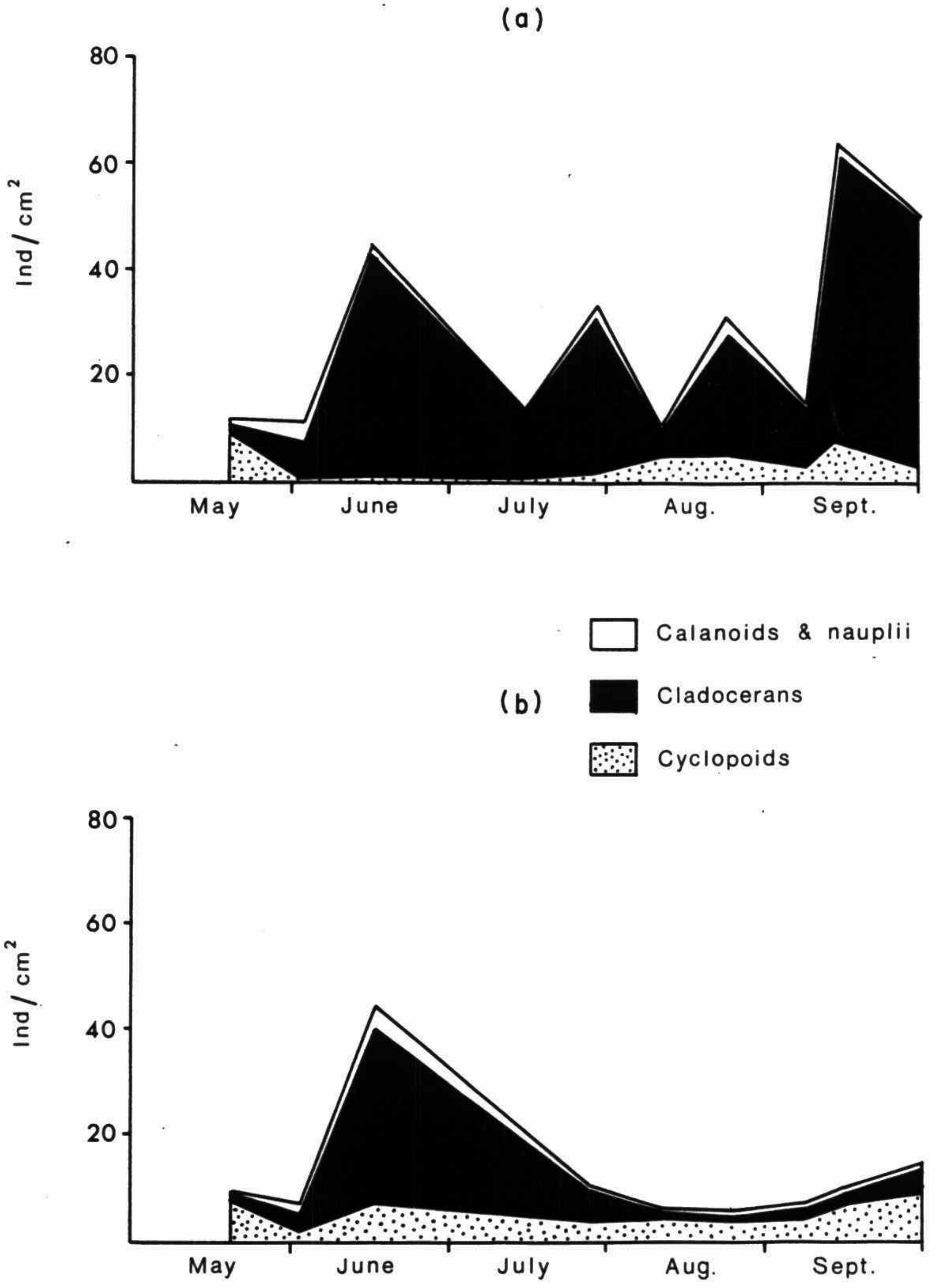


FIG. Ia: Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-I, and (b) C-2 in 1971.

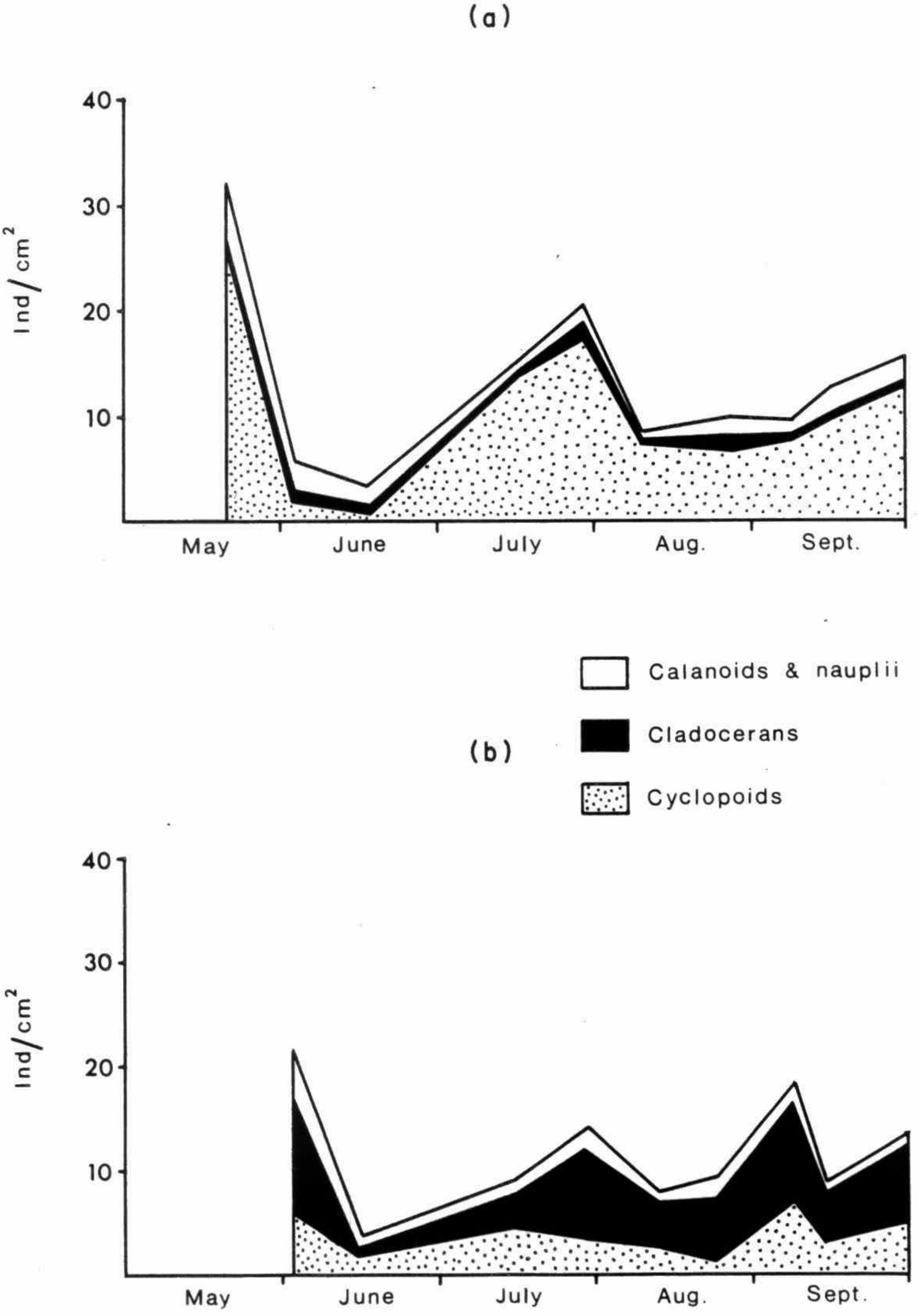


FIG. Ib: Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-3, and (b) C-4 in 1971.

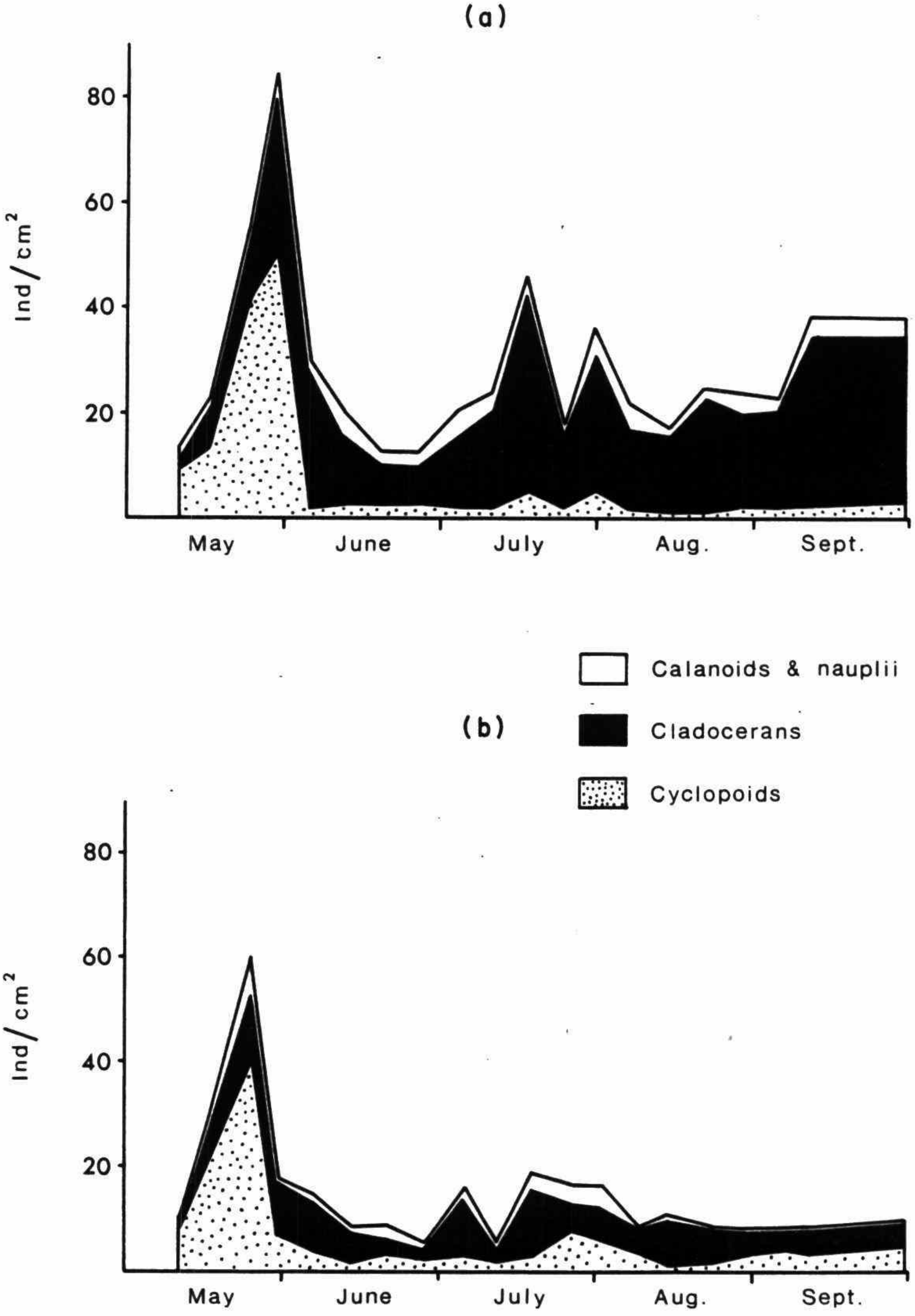


FIG.2a: Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-1, and (b) C-2 in 1972.

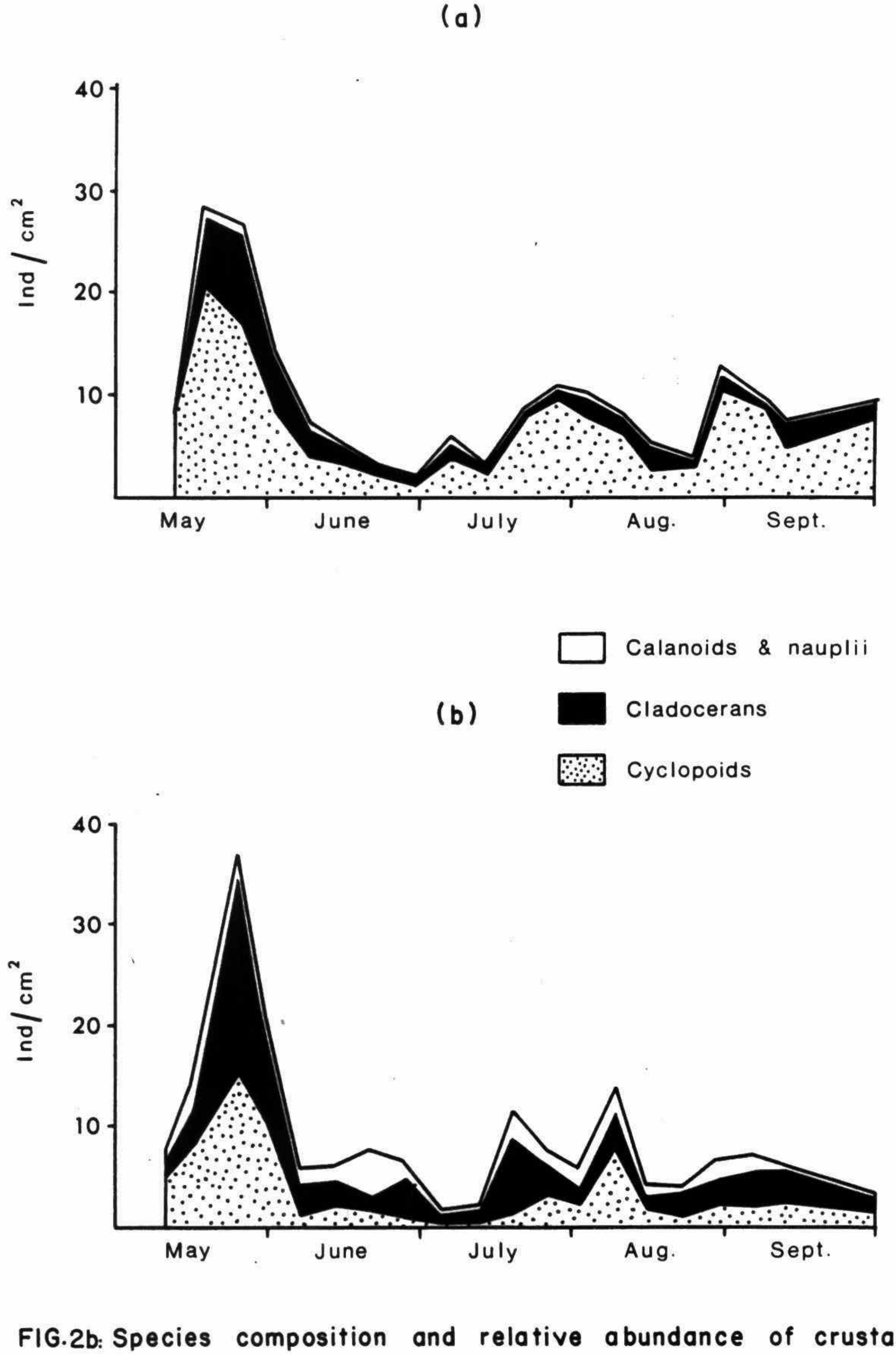
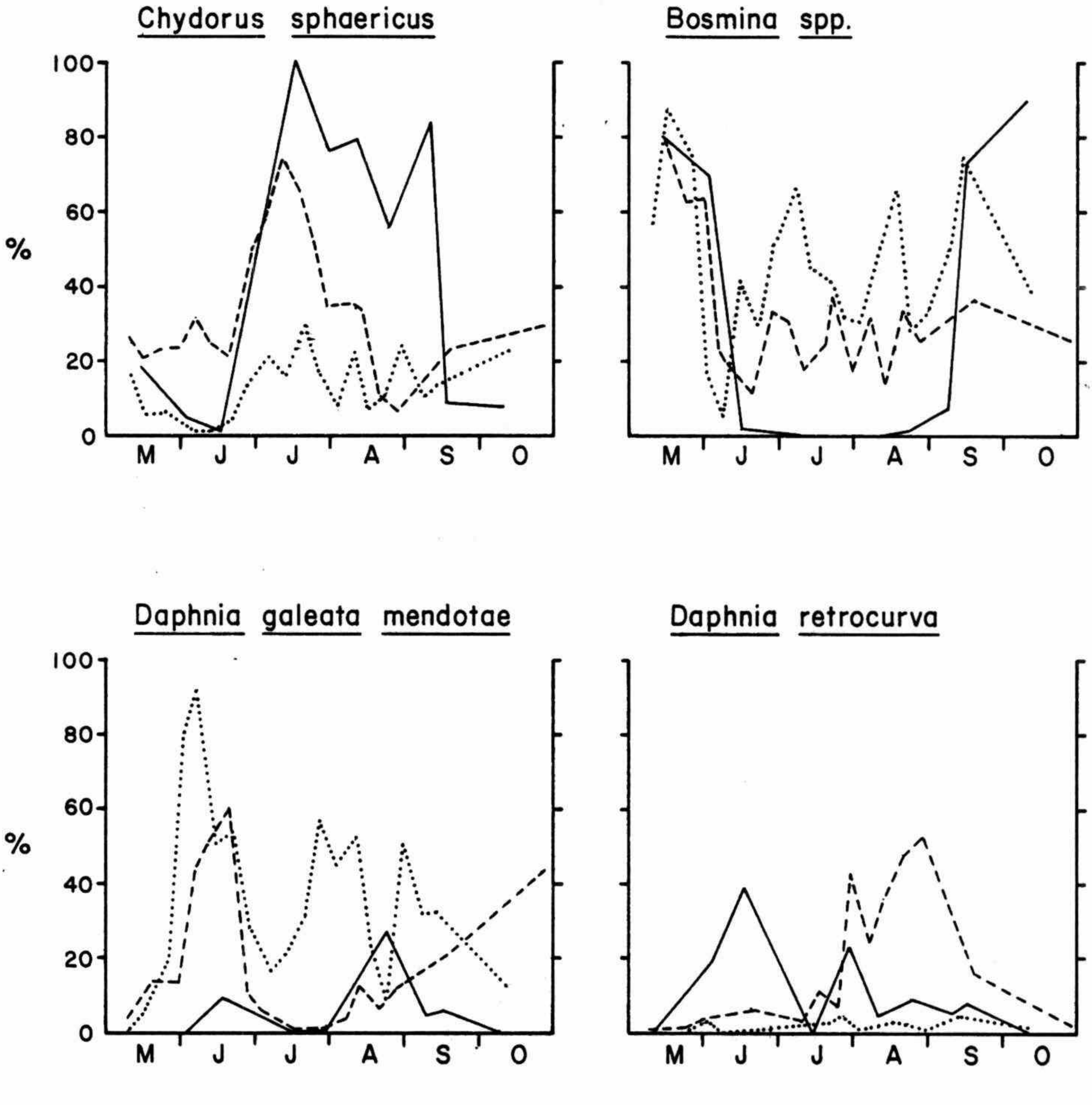


FIG. 2b: Species composition and relative abundance of crustaceans in Chemung Lake at (a) C-3, and (b) C-4 in 1972.



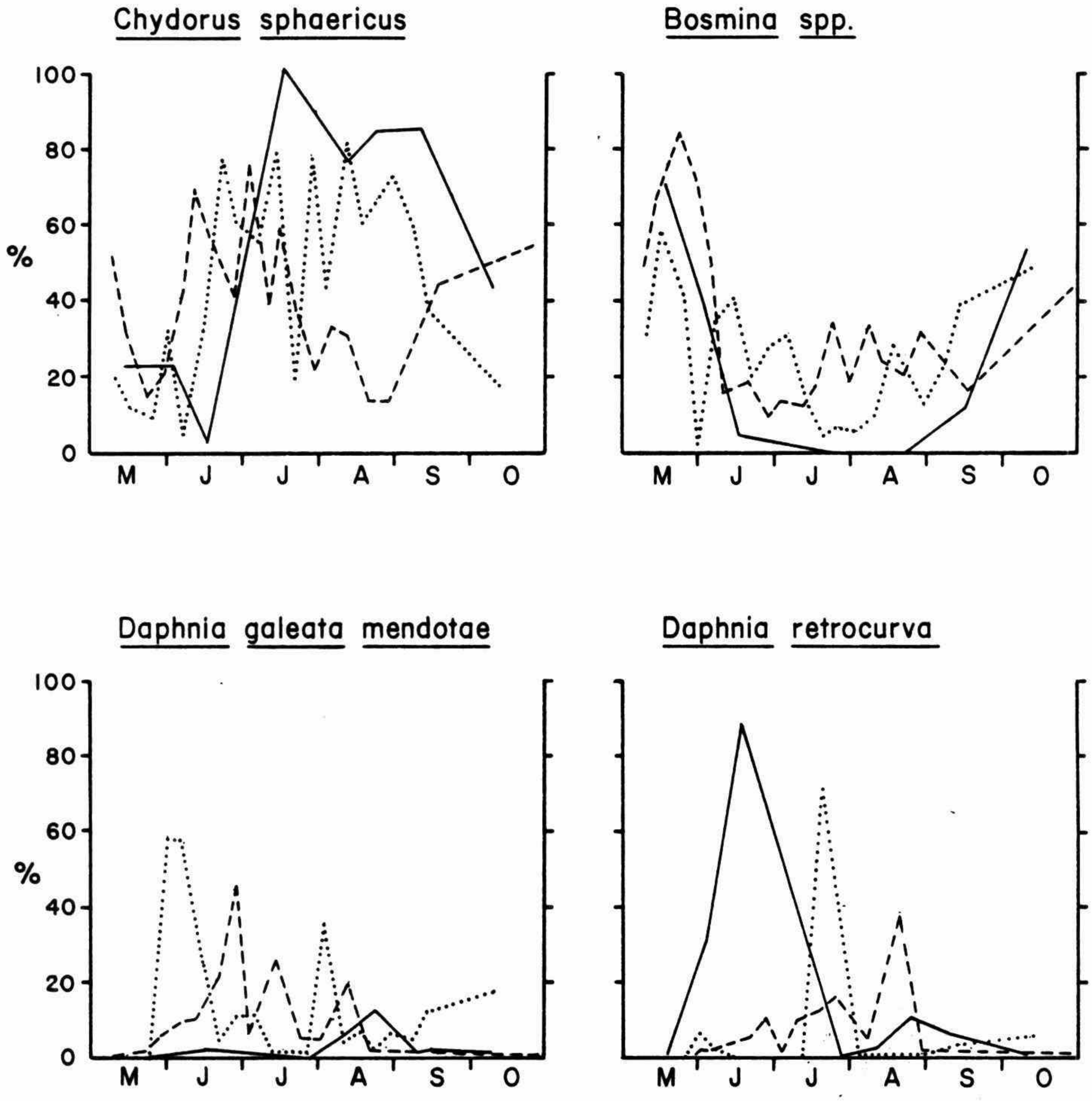
Chydorus sphaericus

Bosmina spp.

Daphnia galeata mendotae

Daphnia retrocurva

FIG.3a: Percentage composition of the cladocerans for the four major species found in Chemung Lake at C-1, in 1971 (——), 1972 (······), and 1974 (- - -).



Chydorus sphaericus

Bosmina spp.

Daphnia galeata mendotae

Daphnia retrocurva

FIG.3b: Percentage composition of the cladocerans for the four major species found in Chemung Lake at C-2, in 1971 (——), 1972 (······), and 1974 (---).

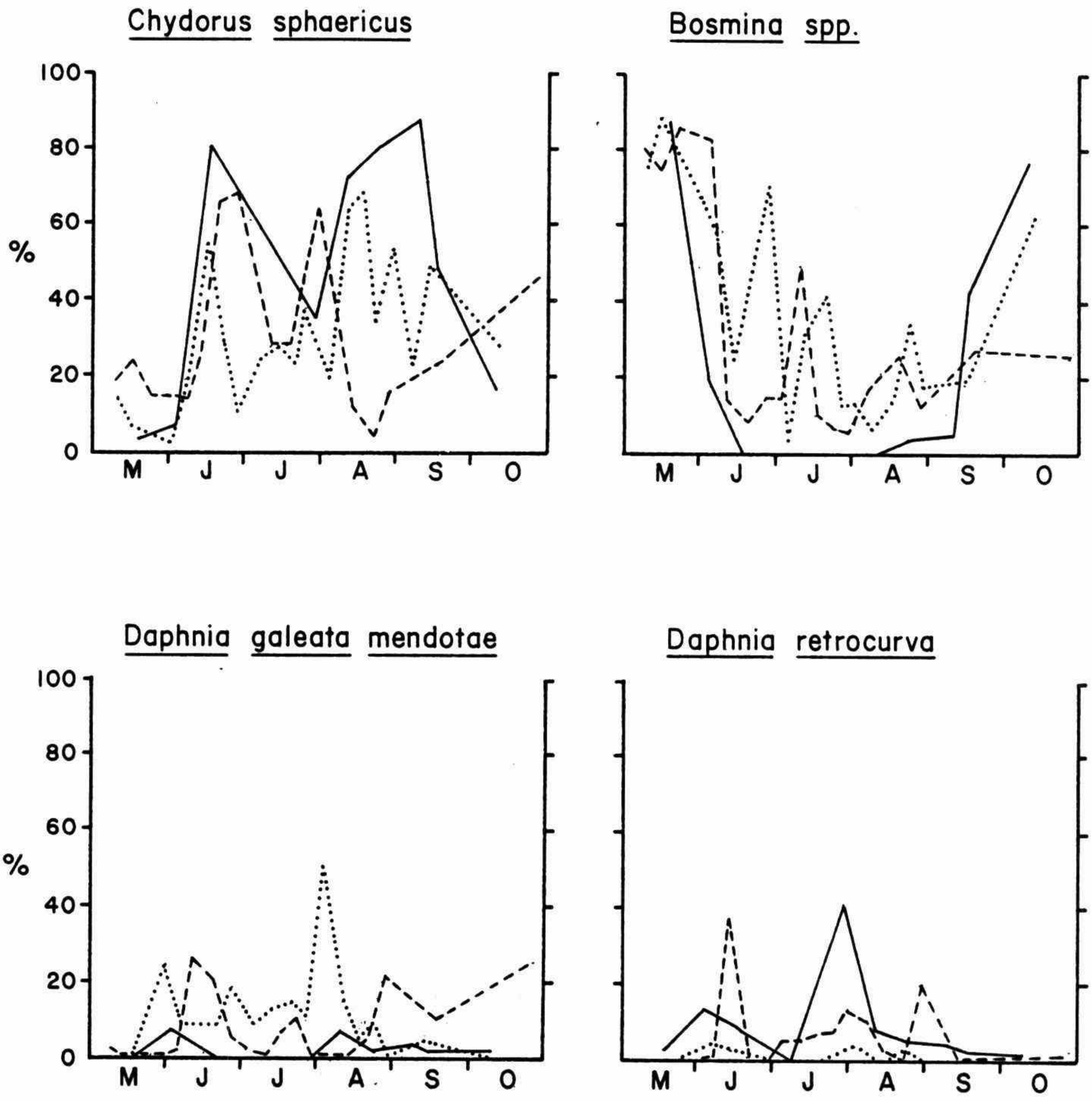


FIG. 3c: Percentage composition of the cladocerans for the four major species found in Chemung Lake at C-4, in 1971 (—), 1972 (……), and 1974 (---).

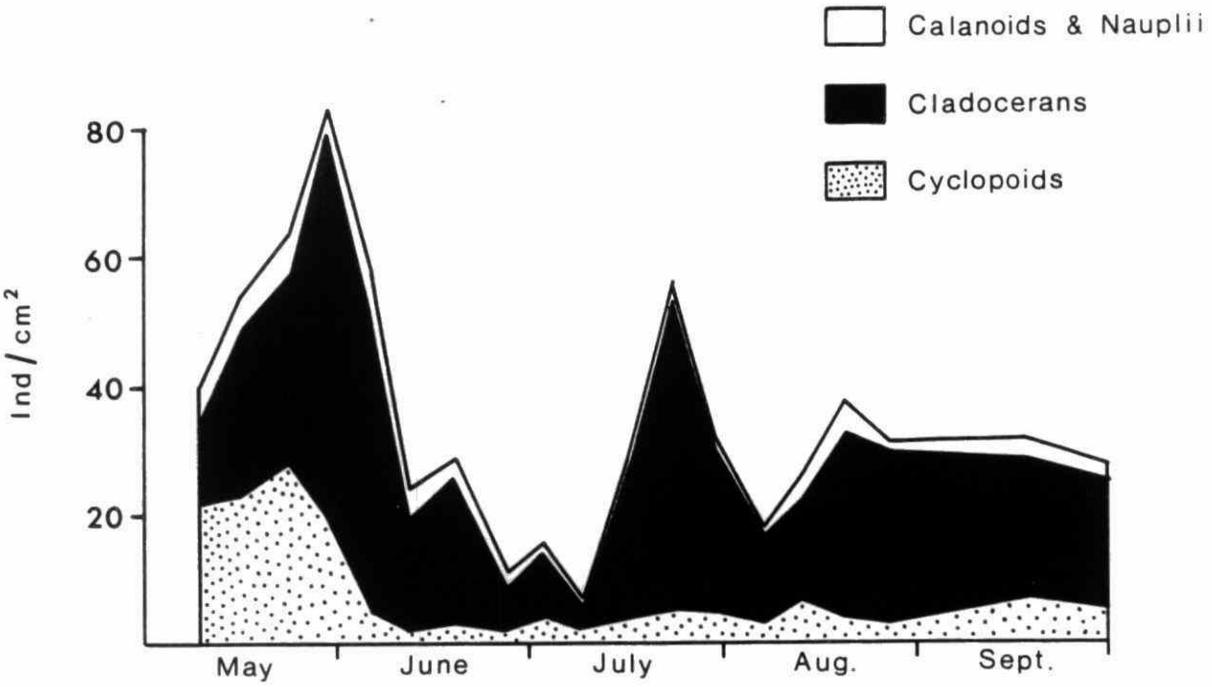


FIG. 4: Species composition and relative abundance of crustaceans in Chemung Lake at C-1 in 1974

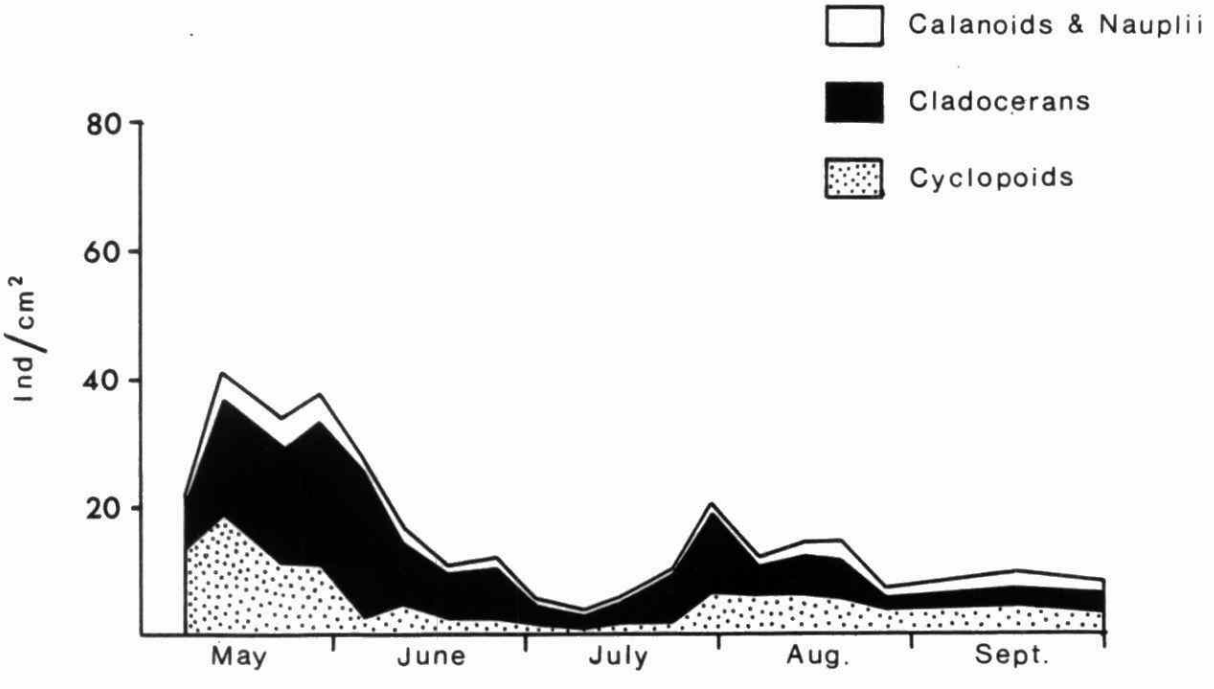


FIG. 5: Species composition and relative abundance of crustaceans in Chemung Lake at C-2 in 1974

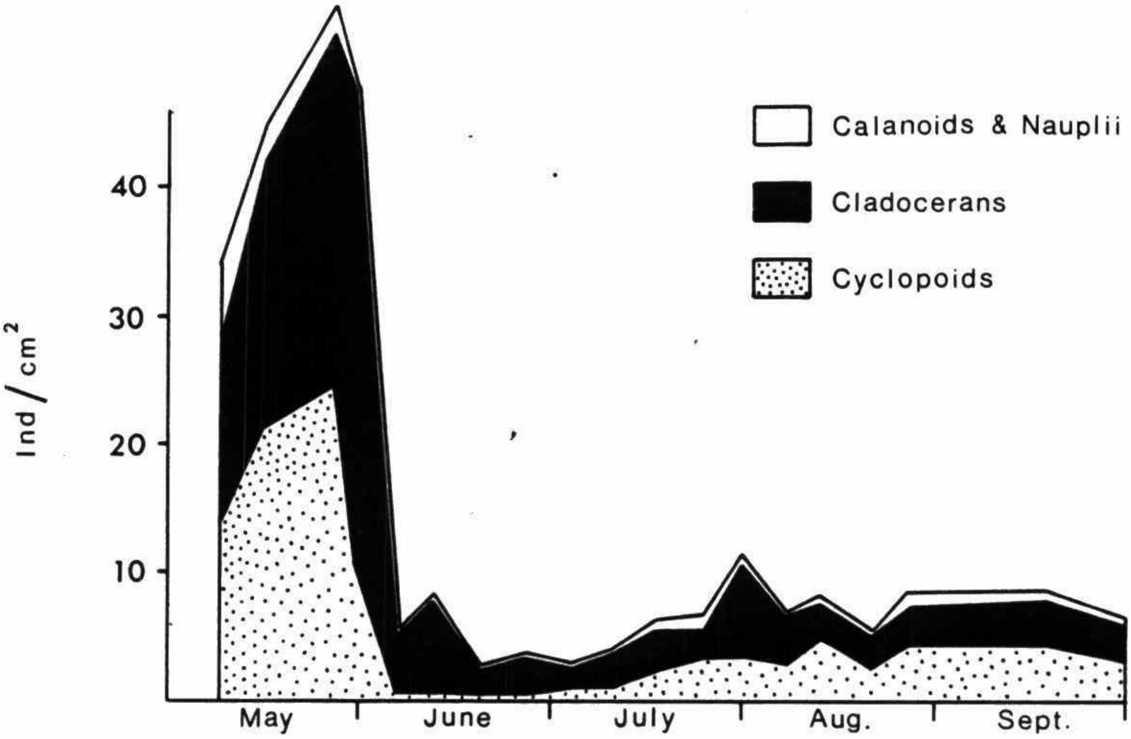


FIG. 6: Seasonal composition and relative abundance of crustaceans in Chemung Lake at C-4 in 1974

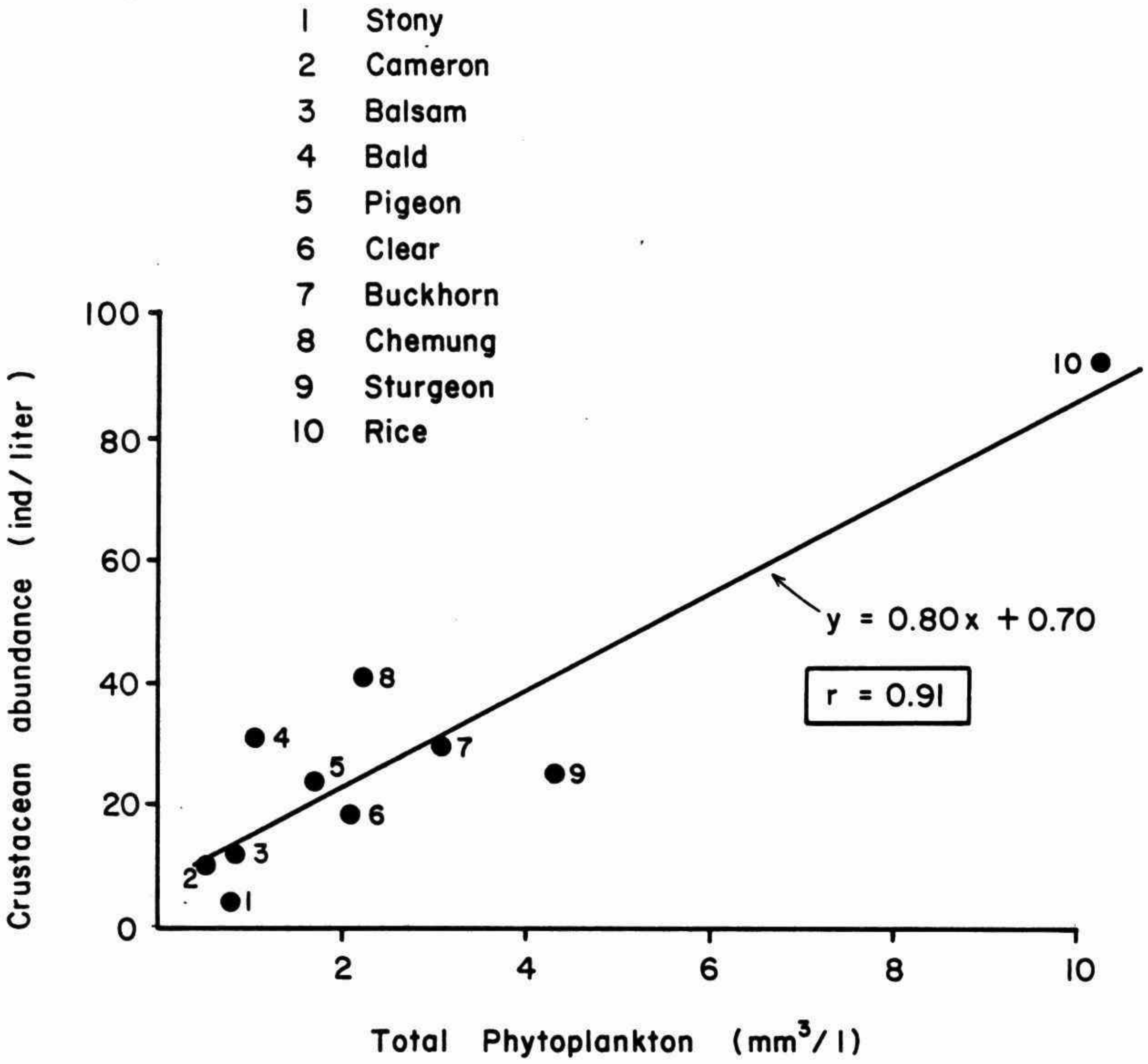


FIG. 7 The relationship between crustacean abundance (individuals/liter) and total phytoplankton (mm^3/l) in the Kawartha Lakes in 1972, based on summer mean values.

CHAPTER 6

THE MACROPHYTES OF SOUTHERN CHEMUNG LAKE (1971 - 1976)

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    (d) Seasonal variations in nitrogen and phosphorus levels (mg/g dry weight) in Chemung Lake macrophytes from May to October, 1976.

INTRODUCTION

Aquatic plants play an important role in aquatic ecosystems by providing food, shelter and attachment for many types of organisms and spawning areas for several species of fish. Through their root systems, they effectively stabilize bottom sediments and through the process of photosynthesis they supply the overlaying waters with dissolved oxygen.

The Kawartha Lakes, including Chemung Lake, have been characterized by prolific growths of submersed macrophytes, mainly due to the presence of extensive shallow areas with rich substrates, which provide an ideal habitat for these plants. In recent years the invasion of Eurasian milfoil, Myriophyllum spicatum L. has further compounded nuisance conditions, impeding many recreational activities such as boating, swimming and water skiing.

In waterways where aquatic plants form a prominent portion of the ecosystem, the aim of management should be directed towards partial control of the vegetation to improve recreational ammenities, rather than total eradication. Any measures violent enough to eradicate the macrophytes are likely to have highly undesirable secondary effects on the overall aquatic environment. Since harvesting of aquatic vegetation has generally been considered as an ecologically sound control measure, a pilot scale operation was initiated in southern Chemung Lake in 1973. Aquatic plant communities in the lake have been monitored since 1971 to assess any changes in specie composition, biomass and nutrient content resulting from the harvesting operation.

METHODS

To determine the actual extent of plant coverage in the lake, remote sensing techniques were used in August of 1972. Colour and infrared imagery was obtained from altitudes ranging between 600 and 3000 m and used to prepare maps of the distribution of the vegetation. (Wile 1973). Data on plant biomass and specie composition was collected at weekly intervals throughout the ice free periods from 40 sampling sites located along visual transects in the weeded section of the lake. (Fig. 1). At each station, a 0.25 m^2 quadrat was dropped on the bottom and all plant material growing within the quadrat was removed by S.C.U.B.A. divers. The plant material was washed, sorted by species and stored in plastic bags for transit to the field laboratory.

The fresh or wet weight of the plant material was determined after all surface adherent water had been removed. The dry weight was obtained by oven-drying (at 105°C) until a constant weight was reached. Ash weight was determined as the residue of ignition at 550°C and the organic weight was expressed as the difference between dry weight and ash weight or the percentage lost on ignition (% LOI). Estimations of plant productivity were determined by the organic weight method, as described by Penfound (1956). The frequency of species occurrence was based on the number of plants of each specie found at the sampling sites and expressed as a proportion of 100% (relative frequency). Plant tissue concentrations of macro and micronutrients were completed at the Ministry of the Environment Toronto laboratory following techniques described elsewhere (Wile and McCombie 1972).

RESULTS AND DISCUSSION

Distribution and Species Composition

Southern Chemung Lake was characterized by prolific growths of submersed aquatic plants which covered an area of some 435 hectares or approximately 50% of the lake surface (Figure 2). Growth of the rooted vegetation was generally confined to those areas of the lake 3 meters or less in depth, undoubtedly due to the limiting effects of light penetration.

Over the six year study period, twenty three species of aquatic plants were identified in the lake (Table 1). Tapegrass, Vallisneria americana and Myriophyllum spp. were the dominant plants, although Chara sp. and Elodea canadensis were also common. The shallow shoreline areas of the lake were largely occupied by mixed communities of plants including elodea, stonewort, naids, pondweeds and tapegrass, whereas milfoil showed a preference for the deeper waters. Many of the pondweeds i.e. Potamogeton crispus matured early in the season and died back by mid-summer. Growth of V. americana usually commenced in late May although the plants were relatively inconspicuous until mid-summer as illustrated in figures 3, 4 and 5. Three species of milfoil, M. exalbescens, M. spicatum and M. heterophyllum were identified in the lake, with the latter specie found only rarely. During 1971 and 1972, M. exalbescens was the prevalent milfoil specie whereas M. spicatum increased dramatically throughout the lake over the remaining four year period, occupying most areas with water depths between 1 and 3 m. This increase in milfoil is apparent when the mid-summer specie composition at the sampling stations in 1976 (figure 6) is compared to figure 4. A similar increase in eurasian milfoil was observed in adjacent lakes (i.e. Buckhorn Lake) although peak levels were reached in 1975, followed by a slight decline in 1976. In southern Chemung Lake the milfoil populations continued to increase between 1975 and 1976 possibly due to the fact that this section of the lake does not form part of the main navigation system and was therefore invaded by this species at a somewhat later date.

Myriophyllum spicatum L. is generally considered to be of Eurasian origin and was first identified in 1902 in Chesapeake Bay, Maryland.

TABLE 1. Aquatic plant species of southern Chemung Lake

SPECIES NAME	COMMON NAME
Bidens beckii Torr.	Water Marigold
Ceratophyllum demersum L.	Coontail
Chara sp.	Chara, Stonewort
Elodea canadensis (Michx.) Planchon	Canada Waterweed
Heteranthera dubia (Jacq.) MacM.	Water Stargrass
Myriophyllum exalbescens Fern.	Water Milfoil
heterophyllum Michx.	Water Milfoil
spicatum L.	Eurasian Water Milfoil
Najas flexilis (Willd.) R. and S.	Bushy Pondweed
Nitella sp.	Nitella
Potamogeton amplifolius Tuckerm.	Bassweed, Big-Leafed Pondweed
crispus L.	Curly-Leafed Pondweed
gramineus L.	Variable Pondweed
pectinatus L.	Sago Pondweed
praelongus Wulfen.	Whitestem Pondweed, Muskie Weed
richardsonii (Ar. Benn.) Rydb.	Richardson's Pondweed
robbinsii Oakes	Robbinson's Pondweed
strictifolius Ar. Benn.	
zosteriformis Fernald.	Flat-Stemmed Pondweed
Ranunculus aquatilis L.	Buttercup, Crowfoot
Sagittaria sp.	Arrowhead
Utricularia vulgaris L.	Bladderwort
Vallisneria americana Michx.	Eelgrass, Tapegrass, Water Celery

Since the late 1950's, this species has spread throughout North America. Most taxonomists (Patten 1954) generally agree that there are definite morphological differences between the Eurasian M. spicatum and the North American M. exalbescens; however, whether these differences are sufficient to justify separating them as species is still a matter of considerable debate.

Curtis (1959) defined weeds as plants which have a rapid growth rate, can surmount high interspecific competition, show great tolerance to regressive influences, can spread and invade in large numbers and have seeds that are tolerant of extreme environmental fluctuations. Eurasian milfoil certainly fulfills these characteristics since it is an extremely aggressive plant with wide ecological amplitude which soon crowds out the more desirable plant species, particularly in deeper waters with soft or organic substrates, and can reproduce both by seeds or fragments. (Nichols and Mori 1971).

The first documented evidence of the presence of M. spicatum in the Kawartha Lakes was provided by Campbell and Webber (1970) during a study of Canal Lake carried out in 1968. The authors further suggest that Canal Lake was infested by this plant five years prior to their 1968 study period. However, due to the previously mentioned discrepancies in milfoil nomenclature, it has not been possible to ascertain whether the plants in question were in fact the eurasian milfoil, M. spicatum L. In Chemung Lake, eurasian milfoil exhibits a rapid growth phase early in the season, generally reaching the water surface by mid to late June, followed by a second growth phase in late summer. Both these growth periods are usually followed by flowering and autofragmentation.

The numerical changes in species composition in southern Chemung Lake (expressed as % relative frequency) over the six year study period are summarized in Table 2. Milfoil increased from 13.9 to 20.3% of the relative frequency between 1971 and 1976. Tapegrass, V. americana and Chara spp. were dominant in 1971 but declined from 21.7% to 15.% and 16.0% to 9.8%, respectively, over the remainder of the study period. The pondweeds generally remained at similar levels or declined slightly whereas Elodea canadensis and Heteranthera dubia showed a fairly pronounced increase.

TABLE 2. Frequency of plant species occurrence in southern Chemung Lake (1971 to 1976).

Species	Frequency (%)						Relative Frequency (%)					
	1971	1972	1973	1974	1975	1976	1971	1972	1973	1974	1975	1976
V. americana	56.1	79.6	86.9	71.3	66.7	49.1	21.7	22.2	19.0	16.6	18.0	15.0
Chara sp.	41.4	48.5	53.6	40.4	32.1	32.2	16.0	13.5	11.7	9.4	8.7	9.8
Myriophyllum spp.	35.9	39.4	63.5	70.0	69.2	66.7	13.9	11.0	13.9	16.4	18.7	20.3
P. zosteriformis	38.9	48.2	48.2	40.6	26.4	21.9	15.0	13.4	10.5	9.5	7.1	6.7
N. flexilis	29.3	35.3	41.9	37.4	43.7	18.9	11.3	9.9	9.1	8.7	11.8	5.8
E. canadensis	13.6	28.9	43.9	51.4	41.8	35.2	5.3	8.1	9.6	12.0	11.3	10.7
P. richardsonii	12.6	11.5	18.0	14.4	7.2	8.2	4.9	3.2	3.9	3.4	1.9	2.5
P. amplifolius	14.4	9.1	8.6	9.9	6.8	4.4	5.5	2.6	1.9	2.3	1.8	1.4
C. demersum	4.6	8.7	8.3	7.4	6.2	5.6	1.8	2.4	1.8	1.7	1.7	1.7
H. dubia	2.0	20.4	27.4	22.5	23.3	28.7	0.8	5.7	6.0	5.3	6.3	8.8
B. beckii	0.5	3.3	12.5	11.6	11.3	5.1	0.2	0.9	2.7	2.7	3.0	1.6
P. strictifolius	2.5	1.2	28.8	24.7	11.9	16.8	1.0	0.3	6.3	5.8	3.2	5.1
P. pectinatus	-	12.4	2.6	10.0	8.1	8.9	-	3.5	0.6	2.3	2.2	2.7
Ranunculus sp.	0.5	5.2	0.9	4.2	2.6	4.0	0.2	1.5	0.2	1.0	0.7	1.2
P. robbinsii	2.5	1.9	5.4	4.6	2.8	3.0	1.0	0.5	1.2	1.1	0.8	0.9
P. crispus	-	-	0.6	4.9	5.0	4.0	-	-	0.1	1.1	1.3	1.2
P. praelongus	-	-	0.3	0.7	-	0.2	-	-	0.1	0.2	-	<0.1
Sagittaria sp.	3.5	1.8	4.3	2.2	4.9	6.3	1.4	0.5	0.9	0.5	1.3	1.9
U. vulgaris	0.5	2.1	3.1	0.1	1.0	-	0.2	0.6	0.7	0.1	0.3	-

Plant Biomass and Production

Seasonal changes in plant biomass (wet and dry weight) over the six year period are illustrated in figures 7 and 8. Seasonal maximum wet weights were generally within the upper section of the 1 - 5 kg/m^2 range reported by Vollenweider (1968) for submersed macrophytes. Peak biomass values (dry weight) attained in late July or August were fairly similar from year to year, ranging between 305 g/m^2 (1973) and 405 g/m^2 (1972). These values are comparable to those reported for fertile aquatic sites (Rickett, 1922; Westlake, 1963; Boyd, 1971).

During the latter years of the study period, seasonal growth patterns show an increase in spring biomass values, due to the early growth phase of *M. spicatum*. Both the early and late summer growth phases of eurasian milfoil are clearly evident on the seasonal biomass curves for 1975 and 1976. In comparison, in 1971 and 1972 when tapegrass, *V. americana* dominated the plant populations, the biomass curves showed a more gradual increase towards a seasonal maxima in August. The effects of changes in species composition on the seasonal distribution of biomass are further illustrated in figures 9 to 14, while the percentage contributions to the annual biomass by the major plant species are summarized in Table 3. In 1971, *V. americana* comprised 63.9% (wet weight) and 38.3% (dry weight) of the annual biomass whereas milfoil (*M. exalbescens*) contributed only 6.4 and 6.8% respectively. By 1976, *V. americana* had decreased dramatically throughout the lake constituting only 13.2% (wet weight) and 7.9% (dry weight) of the plant biomass compared to values of 50.4% (wet wt.) and 47.9% (dry wt.) for water milfoil (*M. spicatum*).

Estimations of net productivity for the macrophytes in southern Chemung Lake were based on changes in the organic weights, as described by Penfound (1956). Organic weights were used in preference to dry or wet weights since they are free of errors due to variable water or ash content. The method provides an estimate of net productivity in plant communities which have marked annual fluctuations in biomass (i.e. in temperate climates) and minimal losses from death or grazing (Westlake 1963). As previously mentioned, some of the pondweed species in Chemung Lake mature early in the season and die back by mid-summer. However, since these species comprise only a small portion of the total biomass, any resultant errors in productivity data can be considered as minimal.

TABLE 3. Percentage contributions by the various aquatic plant species to the total annual biomass.

WET WEIGHT

Species	1971	1972	1973	1974	1975	1976
V. americana	63.9	47.9	55.0	41.5	35.1	13.2
Myriophyllum spp.	6.4	8.6	10.9	26.6	25.9	50.4
Chara sp.	22.0	26.1	19.1	10.8	10.5	15.5
E. canadensis	<1.0	3.8	3.7	4.0	6.8	7.4
N. flexilis	1.6	1.8	1.4	3.5	11.0	3.8
H. dubia	<1.0	5.2	4.4	3.6	5.4	5.1
Others	4.0	6.6	5.4	10.0	5.3	4.6
DRY WEIGHT						
V. americana	38.3	32.5	34.9	25.6	24.2	7.9
Myriophyllum spp.	6.8	8.7	11.1	29.8	25.9	47.9
Chara sp.	44.5	41.2	38.7	21.6	19.8	24.4
E. canadensis	<1.0	4.0	3.4	3.9	7.2	8.4
N. flexilis	2.4	1.8	1.5	3.7	11.1	4.2
H. dubia	<1.0	5.9	3.3	3.0	4.4	3.1
Others	6.0	5.9	8.1	12.4	7.4	4.1

Mean annual production rates, expressed as g/m²/day (organic weight) and mg C/m²/day are summarized in Table 4. Mean daily carbon assimilation rates showed a gradual increase over the study period, no doubt reflecting the explosive growth of M. spicatum. Values were higher than the 680 mg C/m²/day reported by Adam et al. (1974) for Lake Wingra, but were within the lower portion of the 1 - 5 g C/m²/day range reported by Westlake (1963) for submersed aquatic plants. Maximum daily assimilation rates were obtained for pure stands of aquatic plants (Table 5) with values of 3600, 4100 and 4500 mg C/m²/day for V. americana, Chara sp. and M. spicatum, respectively.

Seasonal variations in production rates, based on changes in organic weight per sampling interval, are illustrated in figures 15a, b and c. Maximum production rates occurred early in the season when the plants were actively growing and before peak seasonal biomass values were attained. Westlake (1965) indicated that net productivity per period can become negative before major losses by death or grazing since gross photosynthesis tends to level off in older tissue while respiration increases with increasing biomass, resulting in the premature negative productivity.

Nutrient Concentrations in Plant Tissues

Data on the dry weights of aquatic macrophyte species from southern Chemung Lake has been summarized in Table 6. Average seasonal moisture content showed little year to year intraspecific variability with values ranging between 73.6% for the highly carbonate encrusted Chara sp. to a maximum 94.3% for Sagittaria sp. Conversely, maximum dry weight values were obtained for Chara sp., ranging between 20 and 26.4% of the fresh weights over the six year study period. Lowest values were recorded for Sagittaria sp. and V. americana with dry weights usually representing less than 10% of the fresh weights. Somewhat higher values (10.9 to 14.1%) were obtained for milfoil, thus influencing the amount of dry weight biomass produced in the lake during the latter years of the study. According to Westlake (1965) the dry weight of submersed aquatic plants is usually in the order of 5-20% of the fresh weight, but may exceed 25% if calcareous deposits are present.

Mean and extreme values for organic weights are provided in Table 7. Ash weights of the various plant species generally increased slightly over the growing season due to accumulation of calcareous deposits from photosynthetic processes. The minimum value of 7% of the dry weight was obtained for V. americana and the maximum value of 78% for Chara sp. Mean organic (ash-free) weights ranged between 52 and 84% of the dry weight except for Chara sp., where mean values fluctuated between 28 and 34% over the study period.

TABLE 4. Mean annual macrophyte production (net cumulative productivity) in southern Chemung Lake from 1971 to 1976. (Determined from the difference between maximum and initial organic weight biomass divided by the number of growing days).

Year	Duration of Growth(days)	Initial Organic weight(g/m^2)	Maximum Organic Weight (g/m^2)	Productivity g/m^2/day (organic wt)	Productivity mgC/m^2/day*
1971	84	23	155	1.6	740
1972	90	34	182	1.6	780
1973	68	59	168	1.6	750
1974	98	22	233	2.2	1020
1975	98	30	216	1.9	890
1976	68	26	216	2.8	1320

*Assuming carbon comprises 47% of the organic weight (from Davies 1970).

TABLE 5. Maximum productivity rates in pure species stands in southern Chemung Lake.

Species	Station No. and Year	Duration of Growth (days)	Initial Organic Weight (g/m^2)	Maximum Organic Weight (g/m^2)	Productivity	
					g/m^2/day organic wt.	gC/m^2/day*
Chara sp.	1(1971)	71	66	690	8.8	4.1
V. americana	26(1973)	25	233	425	7.7	3.6
M. spicatum	1(1974)	77	27	773	9.7	4.6

*assuming a carbon content of 47% of the organic weight (from Davies - 1970).

Table 6. Average dry weight of aquatic macrophytes in southern Chemung Lake from 1971 to 1976 (expressed as a % of the fresh weight)

Species	1971	1972	1973	1974	1975	1976
P. amplifolius	18.6	16.8	15.2	14.2	13.1	12.7
P. richardsonii	18.0	15.4	13.1	14.8	11.8	12.9
P. robbinsii	22.7	19.9	19.7	18.6	14.3	15.8
P. zosteriformis	24.7	17.5	16.8	16.5	14.3	16.4
B. beckii	12.6	11.8	10.6	11.4	10.8	9.3
C. demersum	9.4	9.7	11.2	10.9	10.6	9.9
Chara sp.	26.4	20.0	22.7	20.6	20.5	20.3
E. canadensis	17.7	12.7	10.8	10.2	11.4	10.8
H. dubia	12.9	9.5	8.4	8.6	8.9	9.1
Myriophyllum spp.	14.1	12.3	11.3	11.6	10.9	11.9
N. flexilis	18.3	10.4	15.2	11.0	11.0	13.3
Sagittaria sp.	6.9	10.0	9.0	5.7	6.7	7.1
V. americana	9.9	10.2	7.9	8.3	7.9	8.6

Table 7. Organic weights of plant species in southern Chemung Lake from 1971 to 1976 (expressed as a % of dry weight).

	ORGANIC WEIGHTS											
	1971		1972		1973		1974		1975		1976	
Species	range	mean	range	mean	range	mean	range	mean	range	mean	range	mean
P. amplifolius	68-85	78	66-82	74	65-82	74	70-87	79	68-86	76	71-83	78
P. richardsonii	78-90	84	46-86	69	75-87	81	67-88	77	67-84	78	58-84	73
P. robbinsii	67-80	74	-	-	52-74	61	60-88	75	31-84	60	-	-
P. zosteriformis	70-87	79	66-80	74	56-85	74	74-85	78	55-86	76	67-81	74
C. demersum	-	-	55-74	67	77-85	80	70-86	78	73-84	80	-	-
Chara sp.	27-36	30	25-32	28	23-37	29	24-37	31	24-46	34	22-44	34
E. canadensis	72-77	74	65-73	70	53-85	73	58-83	71	66-85	76	65-73	71
H. dubia	-	-	62-74	66	57-72	67	60-83	73	57-82	75	64-87	76
Myriophyllum spp.	52-69	63	65-80	69	42-66	52	44-77	66	39-84	68	46-82	67
N. flexilis	56-75	69	62-66	64	63-72	67	62-80	72	62-78	69	55-74	64
V. americana	65-90	74	41-86	63	58-92	74	66-93	77	50-83	68	44-94	72

Seasonal intraspecific variability was usually in the realm of 20% although changes as high as 40% were obtained for V. americana.

Plant tissue analysis for calcium, magnesium, iron, manganese, potassium and sodium were completed in 1971 and 1973 and the results are summarized in Table 8. The values obtained from the Chemung Lake study are compared to data provided by Boyd (1967) following a literature review of the mineral contents of submersed aquatic plants (Table 9). Calcium concentrations for macrophyte tissues from Chemung Lake were generally higher than the 1.3% average value reported by Boyd, particularly for the highly carbonate encrusted Chara sp. where calcium comprised 13.6 - 27.0 % of the dry weight. Sodium levels were similar except for high values obtained for E. canadensis, H. dubia, N. flexilis and V. americana. Values for the remaining parameters were generally within the ranges reported by Boyd.

Mean and extreme values for nitrogen and phosphorus concentrations in plant tissues are summarized in Table 10. Nitrogen concentrations varied between 1.0% (P. robinsii) and 4.1% (V. americana) of the dry weight for the vasçular aquatic plants with considerably lower values (0.5 - 2.0%) obtained for Chara sp. Phosphorus levels ranged from 0.08% for P. robbinsii to 0.83% for V. americana. Values for Chara sp. fluctuated between 0.03 and 0.13% of the dry weight. Marked fluctuations in interspecific seasonal means for nitrogen and phosphorus were not observed during the study period.

Seasonal variations in nitrogen and phosphorus concentrations in the more common plant species are illustrated in figures 16a, b, c and d. Generally, maximum tissue concentrations of both elements were observed early in the season, followed by a gradual decline over the summer months. Macrophyte communities are capable of accumulating large luxury quantities of inorganic nutrients early in the growing season, thereby effectively competing with phytoplankton for available nutrient supplies (Boyd 1971).

Considerable evidence exists in the literature to indicate that the uptake of nutrients by aquatic plants is greater with increasing ambient levels of these elements. For example, Adams et al. (1971) found significant increases in phosphorus levels and slight increases in nitrogen concentrations in E. canadensis tissues with increasing levels of environmental nutrient enrichment. Similarly, Caines (1965) showed significant increases in P concentrations in plant tissues following addition of calcium superphosphate to their environment. McNabb and Tierney (1971) found a significant linear

TABLE 8. Calcium, magnesium, iron, manganese, potassium, and sodium content of aquatic plants in southern Chemung Lake (expressed as a % of the dry weight)

	Calcium (1971)		Magnesium (1971)		Iron (1971)	
	range	mean	range	mean	range	mean
P. amplifolius	2.0-9.7	4.9	0.07-0.22	0.14	0.05-0.13	0.09
P. richardsonii	0.9-6.0	3.3	0.19-0.33	0.28	0.05-0.12	0.08
P. robbinsii	0.8-2.1	1.5	0.14-0.28	0.19	0.06-0.13	0.09
P. zosteriformis	2.7-10.8	5.4	0.12-1.2	0.45	0.04-0.45	0.13
C. demersum	1.3-5.6	3.5	0.29-0.65	0.44	0.07-0.13	0.10
Chara sp.	13.6-27.0	21.0	0.04-0.39	0.17	0.04-0.11	0.06
E. canadensis	0.7-5.8	4.2	0.10-0.33	0.23	0.12-0.52	0.36
H. dubia	1.3-5.5	3.4	0.18-0.29	0.24	0.18-0.25	0.22
Myriophyllum spp.	4.3-13.5	9.7	0.09-0.36	0.21	0.08-0.34	0.16
N. flexilis	3.8-13.0	7.7	0.18-0.47	0.32	0.06-0.20	0.11
V. americana	0.9-6.4	3.8	0.14-0.49	0.23	0.06-0.55	0.24

	Manganese (1971)		Potassium (1973)		Sodium (1973)	
P. amplifolius	0.01-0.11	0.05	0.9-2.1	1.5	0.27-0.59	0.49
P. richardsonii	0.01-0.08	0.03	0.6-2.4	1.5	0.41-1.0	0.62
P. robbinsii	0.03-0.12	0.06	0.22-0.90	0.6	0.23-0.66	0.37
P. zosteriformis	0.02-0.12	0.06	0.28-1.2	0.7	0.33-0.42	0.38
C. demersum	-	-	0.90-3.2	2.3	0.43-0.83	0.55
Chara sp.	0.02-0.33	0.10	0.20-0.55	4.1	0.12-0.23	0.19
E. canadensis	0.04-0.68	0.23	1.0 -2.7	1.8	0.27-1.5	1.05
H. dubia	0.04-0.07	0.06	1.0 -3.5	2.2	0.22-1.3	0.95
Myriophyllum spp.	0.04-0.09	0.07	1.1 -1.7	1.3	0.44-0.91	0.63
N. flexilis	0.02-0.05	0.03	0.56-2.4	1.2	0.98-1.9	1.29
V. americana	0.02-.17	0.07	1.7 -7.0	4.7	0.29-3.0	1.75

TABLE 9. Ranges in mineral concentrations for Chemung Lake macrophytes compared to those found by Boyd (1967). Values are expressed as a % of dry weight.

	Chemung Lake	Boyd (1967)	
Ca	0.7 - 27%	1.3%	(as high as 14% on marl encrusted plants)
Mg	0.07 - 1.2%	<0.7%	(as high as 1% on marl encrusted plants)
Na	0.12 - 3.0%	<0.5%	(some species capable of accumulating large quantities)
K	0.2 - 7.0%	1-6%	(extremely variable)
Fe	0.04 - 0.55%		considerable interspecific variation
Mn	0.01 - 0.68%		considerable interspecific variation

TABLE 10. Nitrogen and phosphorus content of macrophyte species in southern Chemung Lake (expressed as a % of dry weight).

	NITROGEN											
	1971		1972		1973		1974		1975		1976	
Species	range	mean	range	mean	range	mean	range	mean	range	mean	range	mean
P. amplifolius	1.6-3.0	2.2	1.7-2.4	1.9	1.6-2.5	1.9	1.6-3.4	2.2	1.6-2.7	2.1	1.9-2.9	2.3
P. richardsonii	2.0-3.4	2.5	1.6-2.4	2.0	1.8-3.5	2.2	1.5-3.5	2.4	1.7-3.6	2.5	1.0-3.5	2.2
P. robbinsii	2.3-3.3	2.4	1.3-1.7	1.5	1.0-2.4	1.6	1.6-2.9	2.0	1.8-3.2	2.3	-	-
P. zosteriformis	1.6-3.5	2.3	1.7-2.6	2.0	1.2-2.0	1.7	1.6-2.8	2.2	1.9-2.6	2.3	1.6-3.3	2.2
C. demersum	1.9-3.1	2.6	1.7-2.8	2.3	1.6-2.2	1.9	1.5-2.8	2.2	1.9-2.4	2.2	-	-
Chara sp.	0.7-1.5	0.9	0.5-1.2	0.9	0.5-1.2	0.8	0.6-1.5	0.9	0.6-1.3	0.9	0.5-2.0	1.2
E. canadensis	1.7-3.1	2.4	1.7-2.2	1.9	1.7-2.1	1.9	1.1-2.8	2.2	1.5-3.1	2.0	1.8-2.7	2.3
H. dubia	1.7-1.8	1.8	1.7-2.2	2.1	1.6-2.8	2.0	1.5-2.6	2.0	1.5-2.8	2.1	1.2-2.4	2.0
Myriophyllum spp.	1.5-2.7	2.0	1.6-2.6	2.1	1.5-2.8	1.8	1.5-2.9	2.2	1.4-4.1	2.4	1.6-3.3	2.3
N. flexilis	1.6-4.3	2.3	1.4-3.1	2.2	1.4-2.3	1.8	1.5-3.0	2.2	1.5-2.2	2.0	1.6-2.4	2.2
V. americana	1.9-2.9	2.3	1.2-2.9	1.9	1.4-3.1	2.4	2.2-3.4	2.8	1.6-4.1	2.2	1.2-3.6	2.5
	PHOSPHORUS											
P. amplifolius	.12-.24	.19	.10-.20	.16	.11-.28	.16	.11-.34	.17	.11-.24	.16	.11-.27	.17
P. richardsonii	.14-.51	.27	.21-.30	.24	.16-.60	.28	.16-.50	.28	.13-.49	.24	.08-.61	.29
P. robbinsii	.18-.45	.28	.12-.13	.13	.08-.18	.13	.11-.15	.13	.09-.23	.14	-	-
P. zosteriformis	.12-.26	.19	.18-.39	.24	.12-.27	.20	.16-.28	.19	.11-.24	.18	.15-.36	.25
C. demersum	.11-.16	.18	.18-.37	.27	.15-.33	.23	.15-.32	.23	.20-.24	.22	-	-
Chara sp.	.06-.12	.08	.06-.12	.09	.03-.12	.08	.06-.13	.09	.06-.12	.09	.04-.11	.09
E. canadensis	.16-.34	.27	.17-.40	.29	.18-.33	.26	.15-.29	.23	.19-.39	.26	.18-.42	.27
H. dubia	.16-.27	.22	.16-.31	.26	.12-.48	.25	.14-.38	.21	.15-.30	.21	.14-.37	.24
Myriophyllum spp.	.18-.29	.22	.18-.30	.24	.17-.44	.24	.18-.31	.25	.13-.47	.25	.15-.55	.27
N. flexilis	.10-.39	.21	.20-.24	.26	.10-.26	.17	.15-.47	.32	.14-.29	.20	.17-.20	.18
V. americana	.17-.60	.30	.11-.60	.26	.14-.58	.29	.21-.42	.30	.17-.83	.30	.09-.43	.26

regression between phosphorus uptake by *Ceratophyllum demersum* and ambient levels above 12 µg/l P. A similar relationship was found for the Kawartha Lakes with phosphorus concentrations in plant tissues reflecting the increasing enrichment of the waters from Balsam to Rice Lake (Kawartha Lakes Water Management Study. 1976).

Gerloff and Krombholz (1966) used tissue analysis as an index of the availability of N and P in lakes for plant growth and established critical tissue concentrations of 1.3% N and 0.13% P in laboratory experiments with angiosperm aquatic plants. Tissue concentrations above these critical limits would have no effect on biomass production and represent luxury uptake. Values below the critical levels indicate that plant growth is limited by the availability of that element. In a similar series of experiments, Wilson (1972) found critical phosphorus tissue concentrations for *Myriophyllum exalbescens* in the range of 0.06 to 0.08%. Subsequent studies by Gerloff (1975) established critical tissue levels of 0.75% N, 0.07% P and 0.35% K for *M. spicatum*. In Chemung Lake tissue concentrations for *Myriophyllum spp*. were well above these critical levels ranging between 1.4 and 4.1% for N, 0.13 and 0.55% for P and 1.1 and 1.7% for K, over the study period. Similarly tissue concentrations for the other angiosperm plants were generally well above Gerloff's (1966) critical levels of 1.3% N and 0.13% P, indicating that plant growth in the lake was not restricted by nutrient availability.

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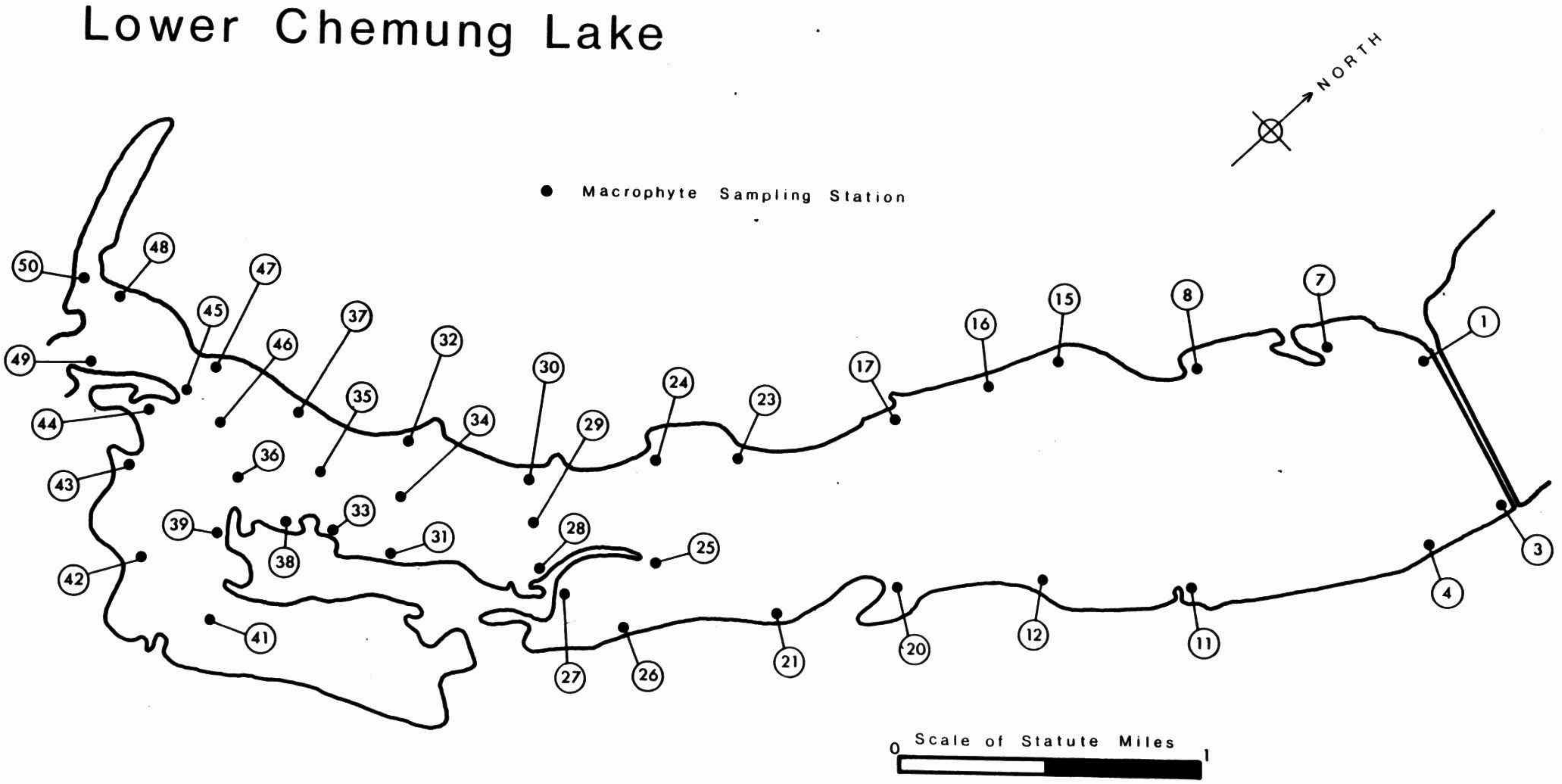

FIG. 1. Macrophyte sampling stations in Chemung Lake.

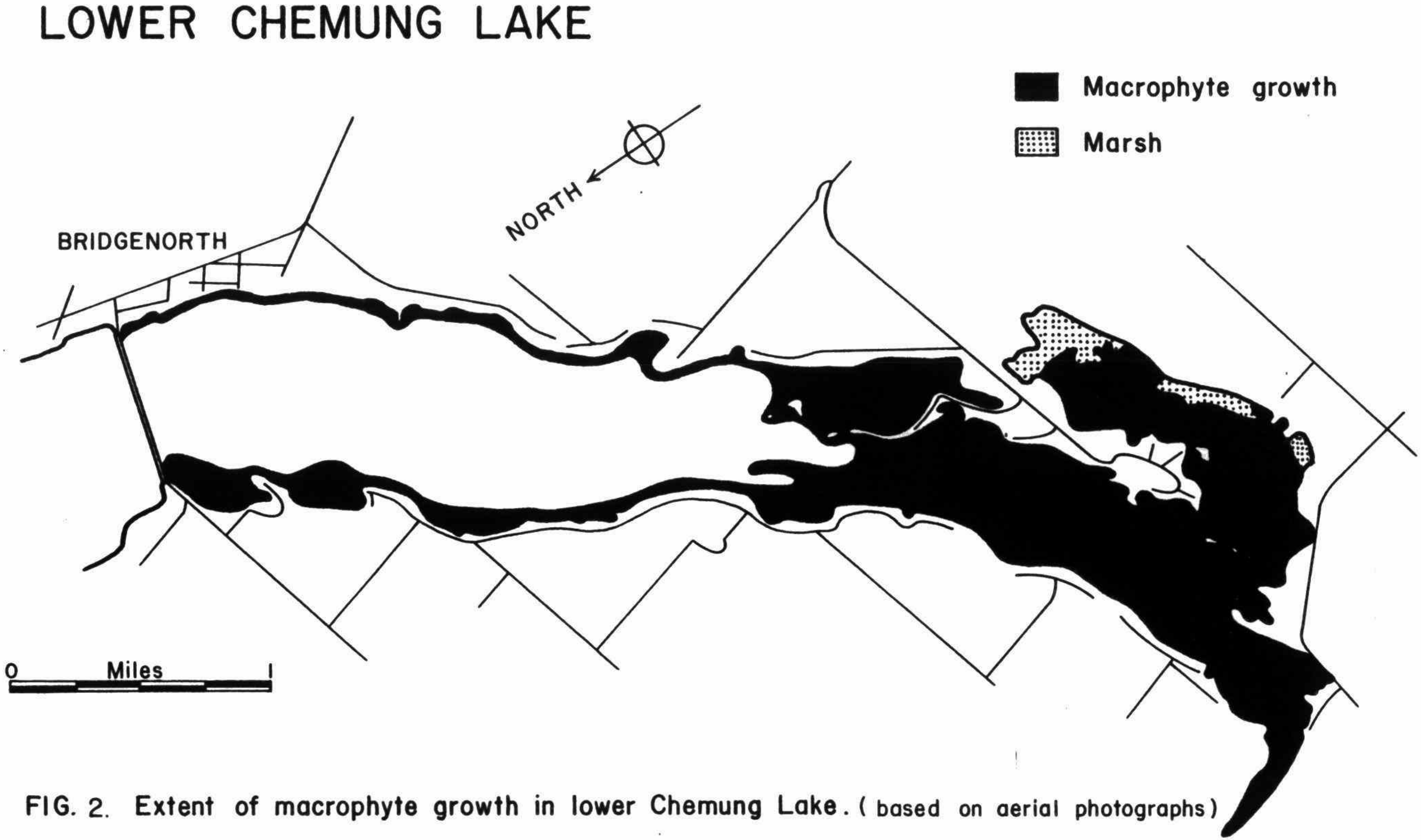

FIG. 2. Extent of macrophyte growth in lower Chemung Lake. (based on aerial photographs)

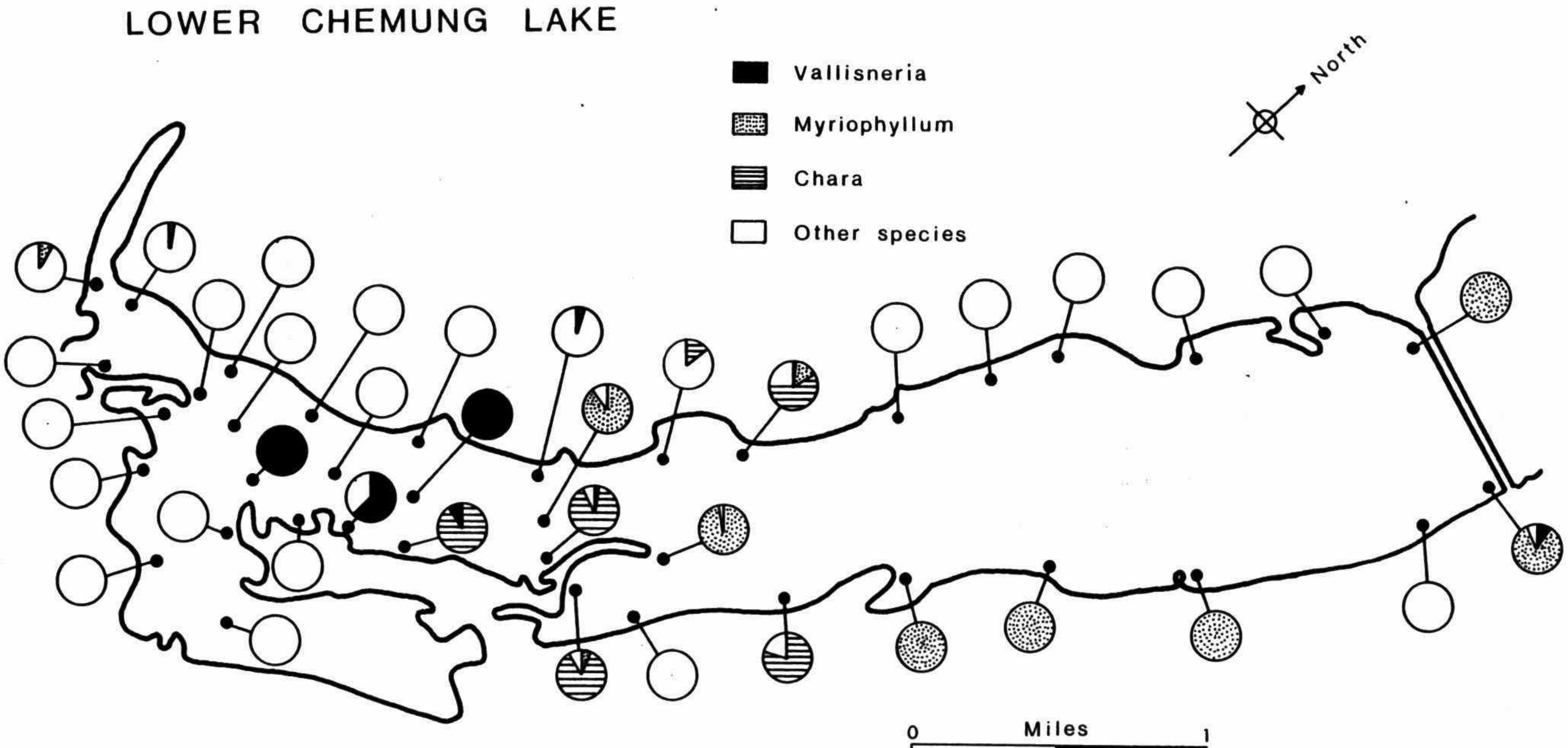

FIG. 3. Macrophyte species composition in Lower Chemung Lake, May 13-16, 1974.

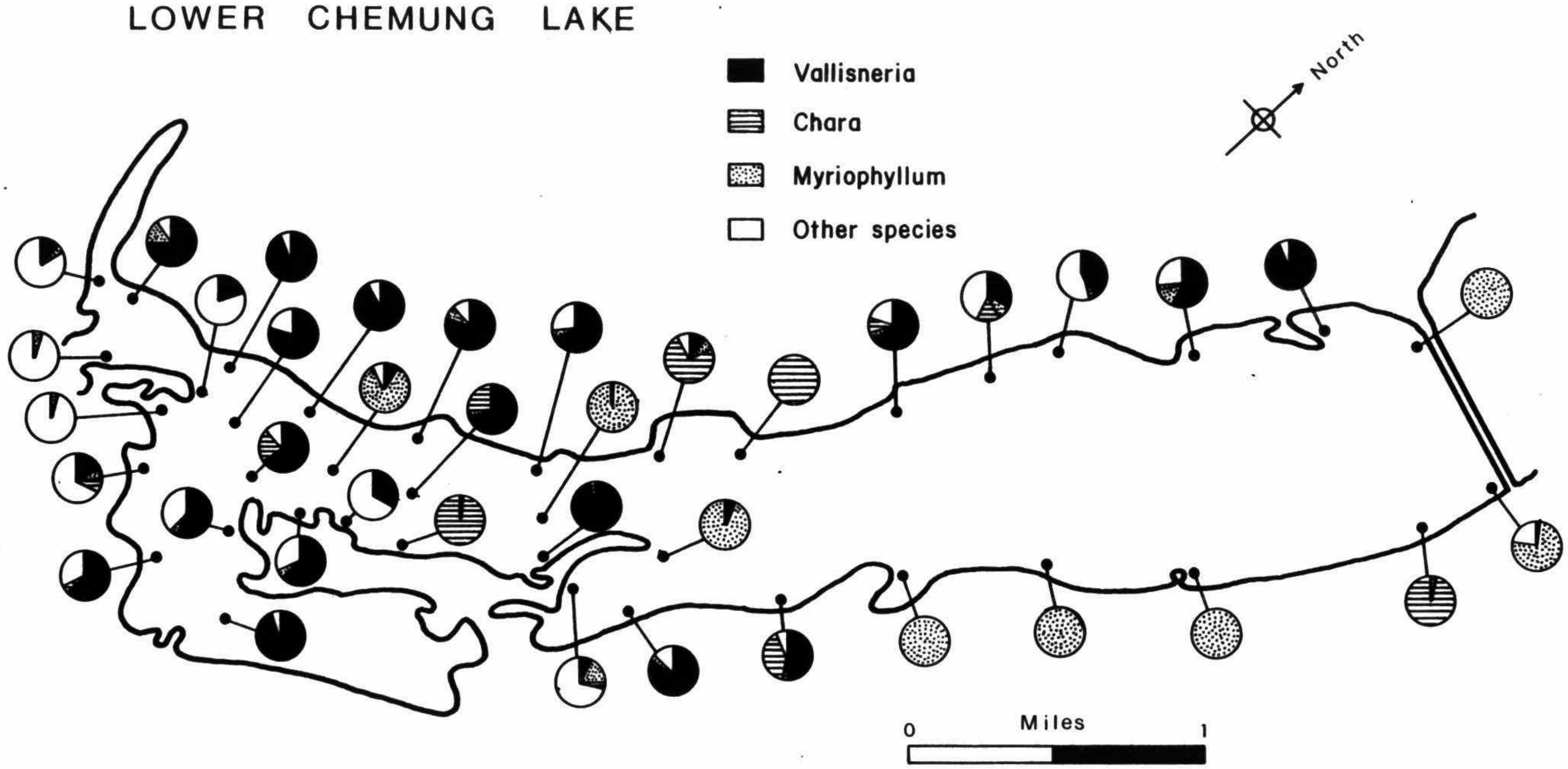

FIG. 4. Macrophyte species composition in Lower Chemung Lake, July 22-26, 1974.

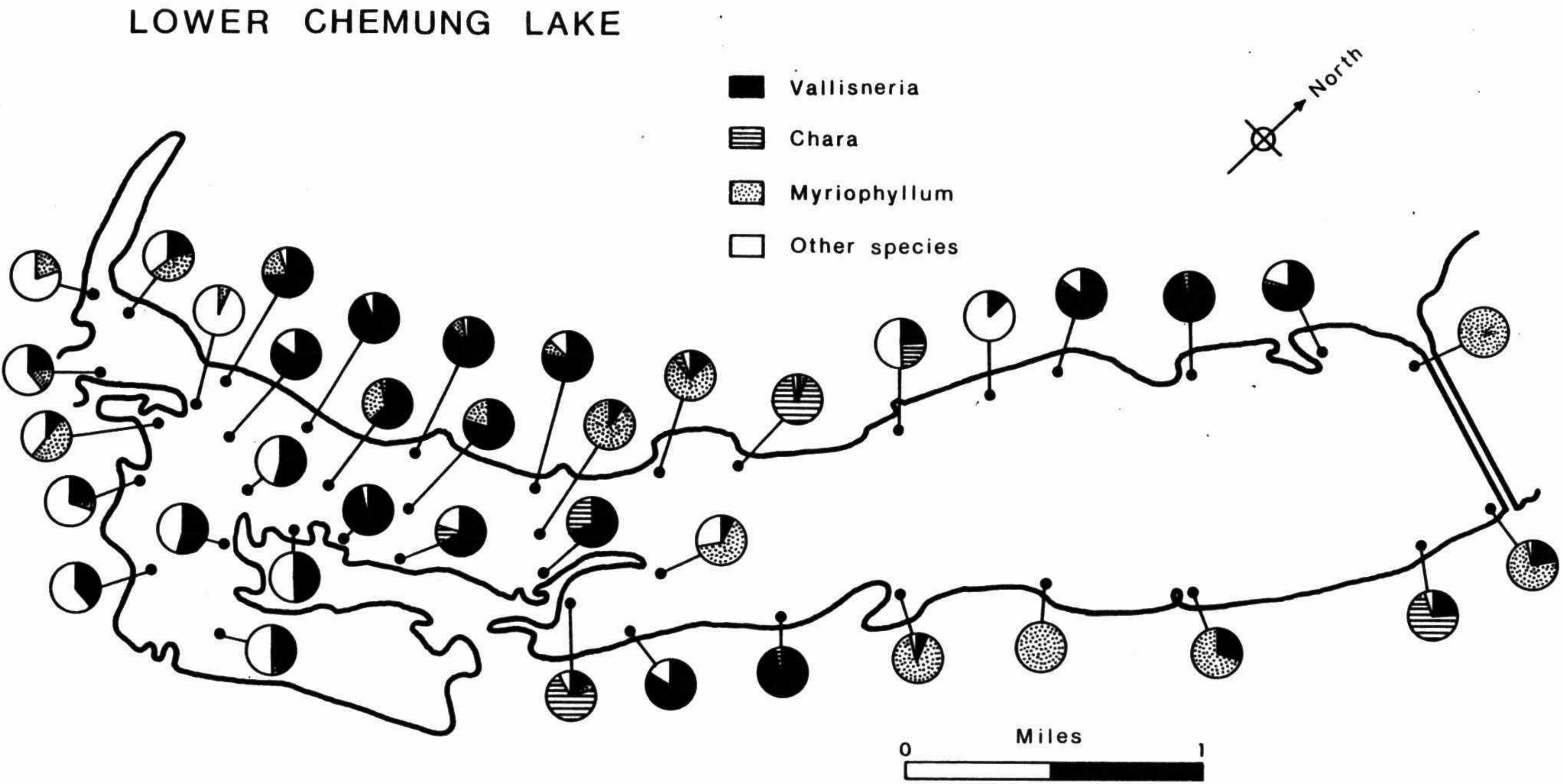

FIG. 5. Macrophyte species composition in lower Chemung Lake, September 10-12, 1974.

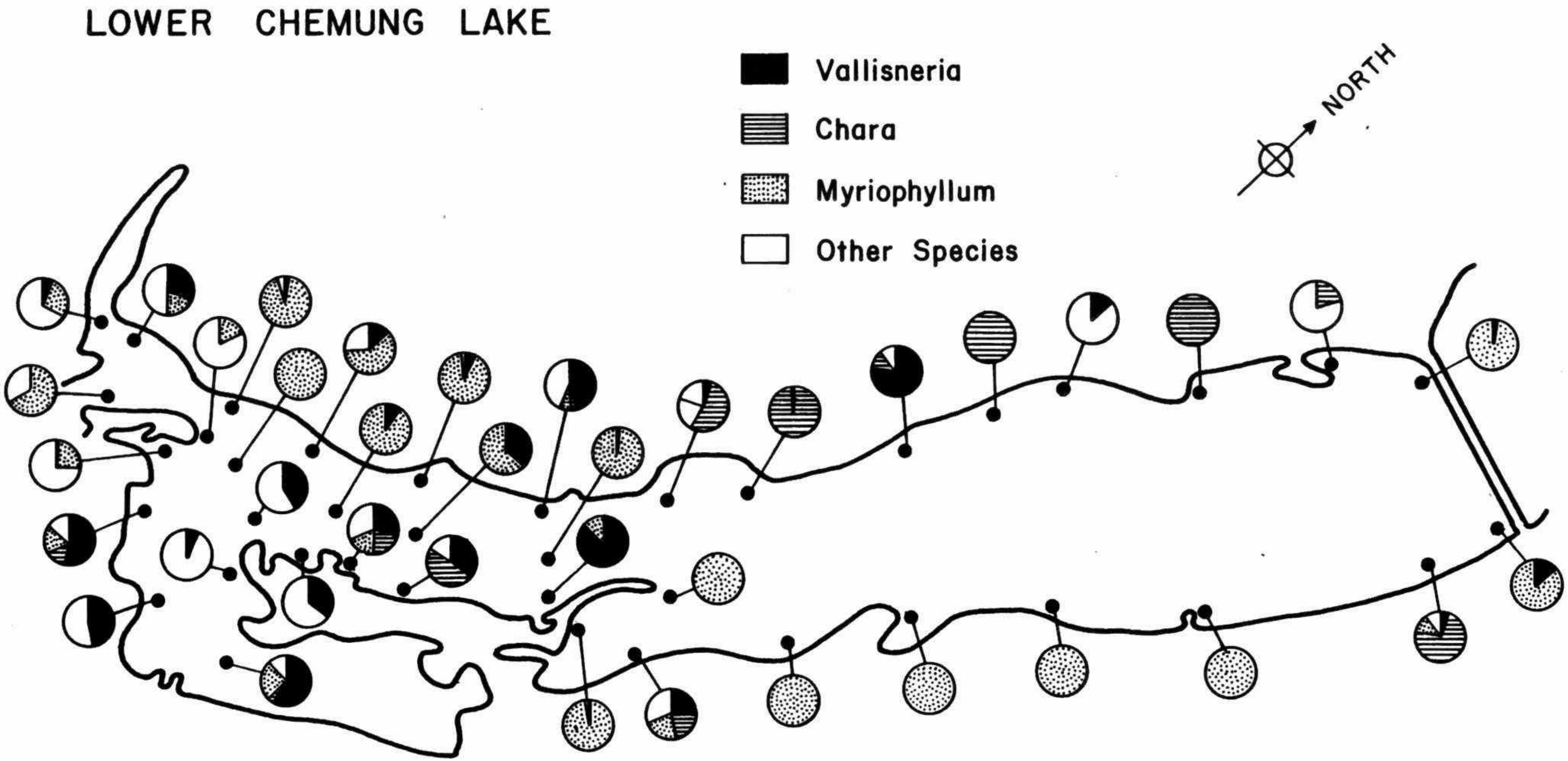

FIG. 6. Macrophyte species composition in Lower Chemung Lake, July 20-22, 1976.

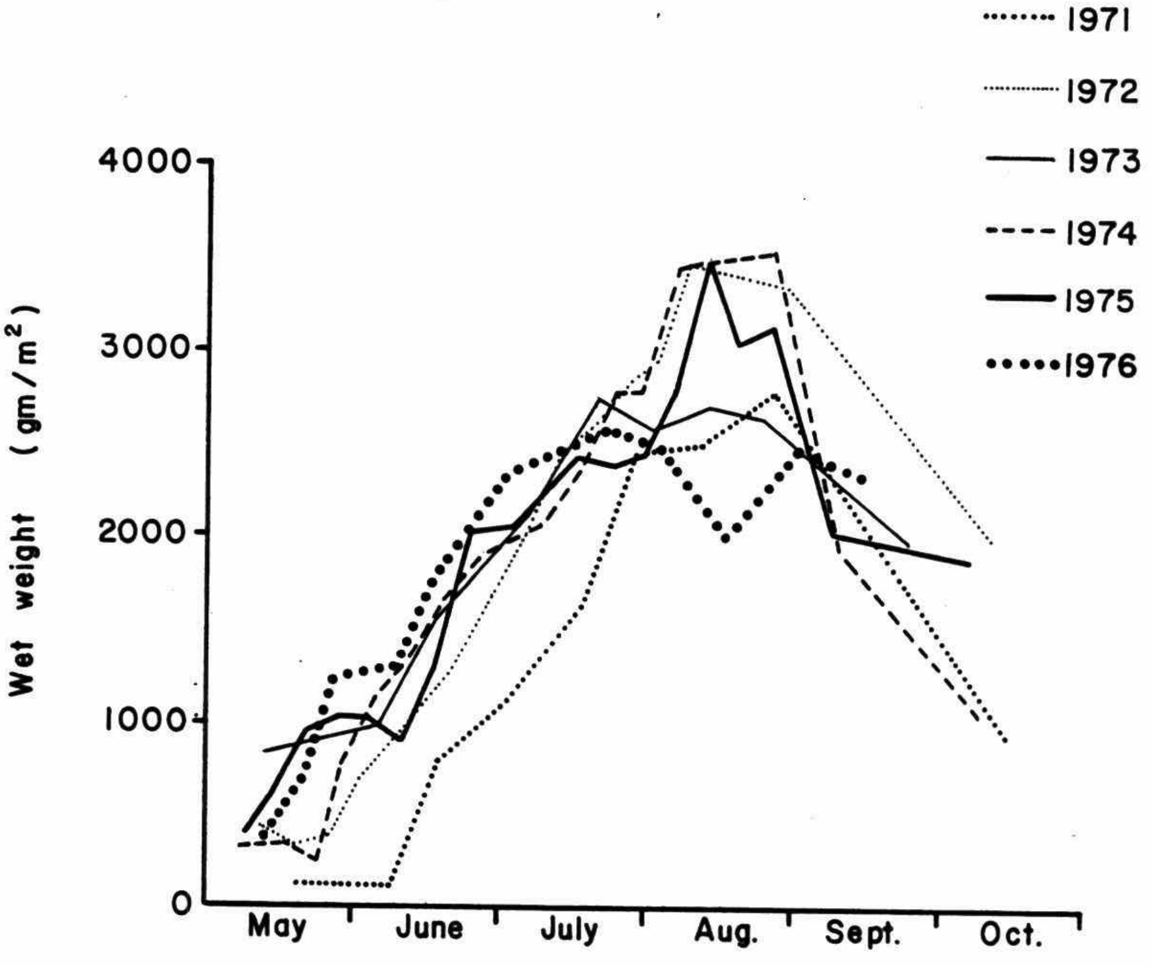

FIG. 7. Wet weight (gm/m^2) of aquatic plants in lower Chemung Lake from 1971 to 1976.

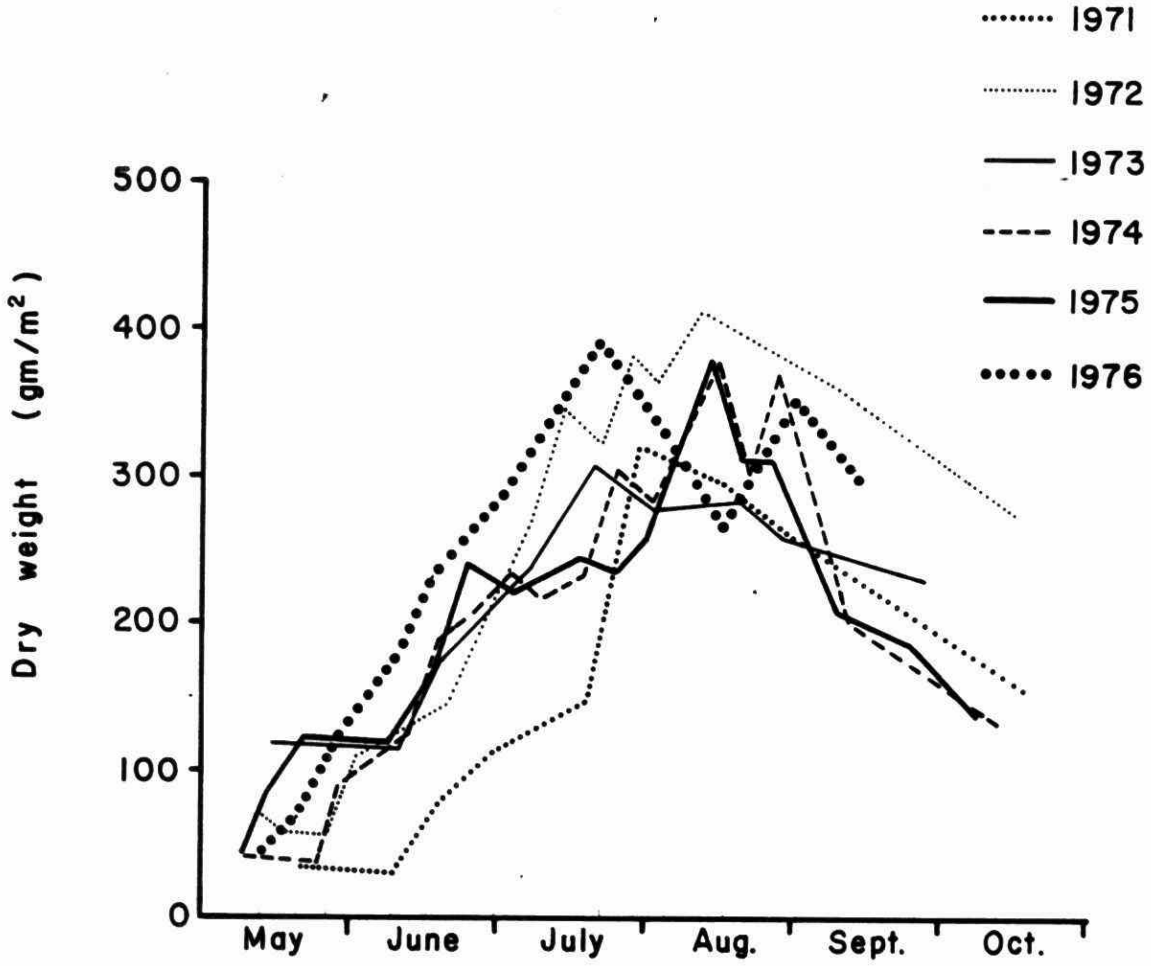

FIG. 8. Dry weight (gm/m^2) of aquatic plants in lower Chemung Lake from 1971 to 1976.

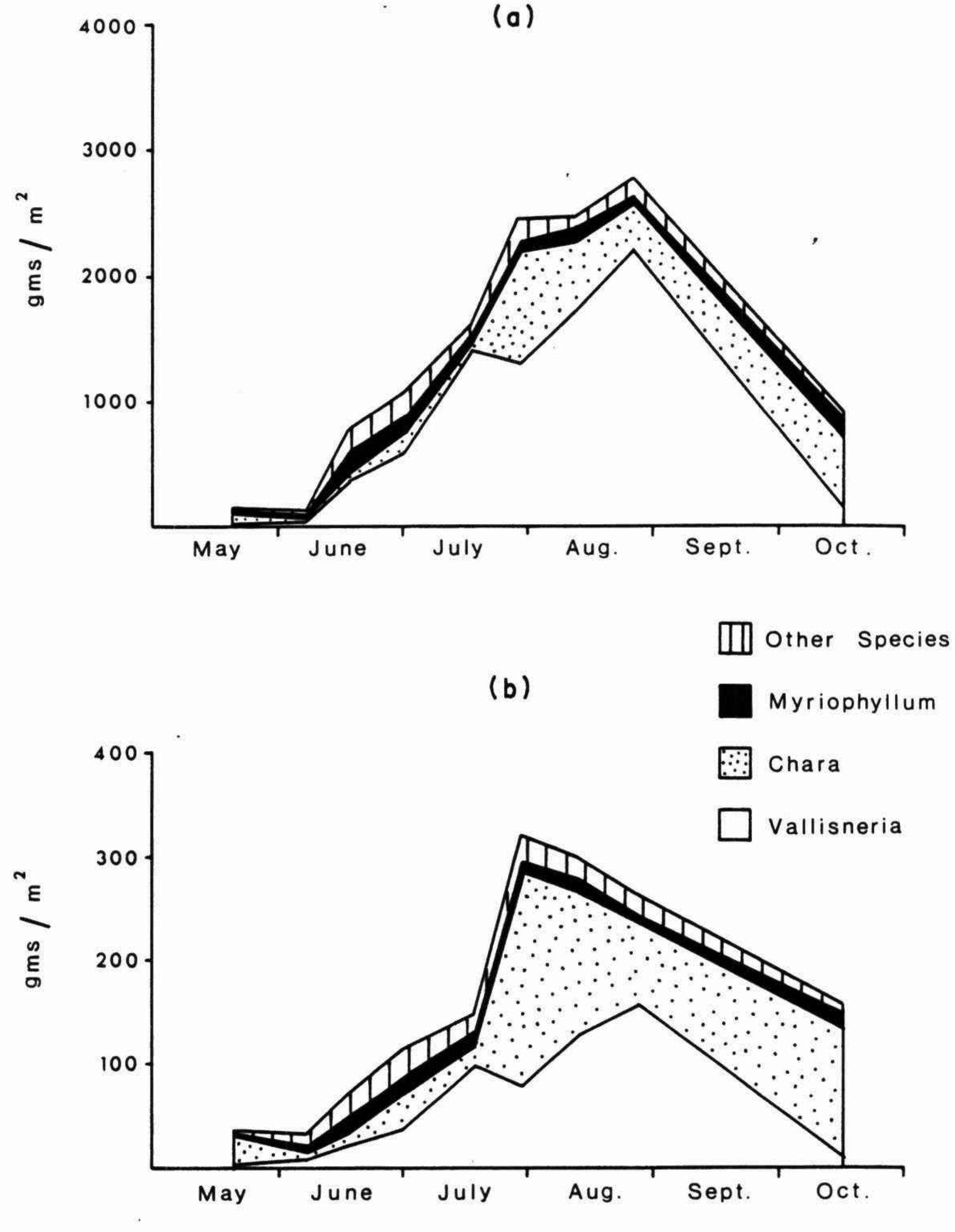

FIG. 9. Seasonal variations in macrophyte biomass in Chemung Lake in 1971; (a) wet weight, (b) dry weight.

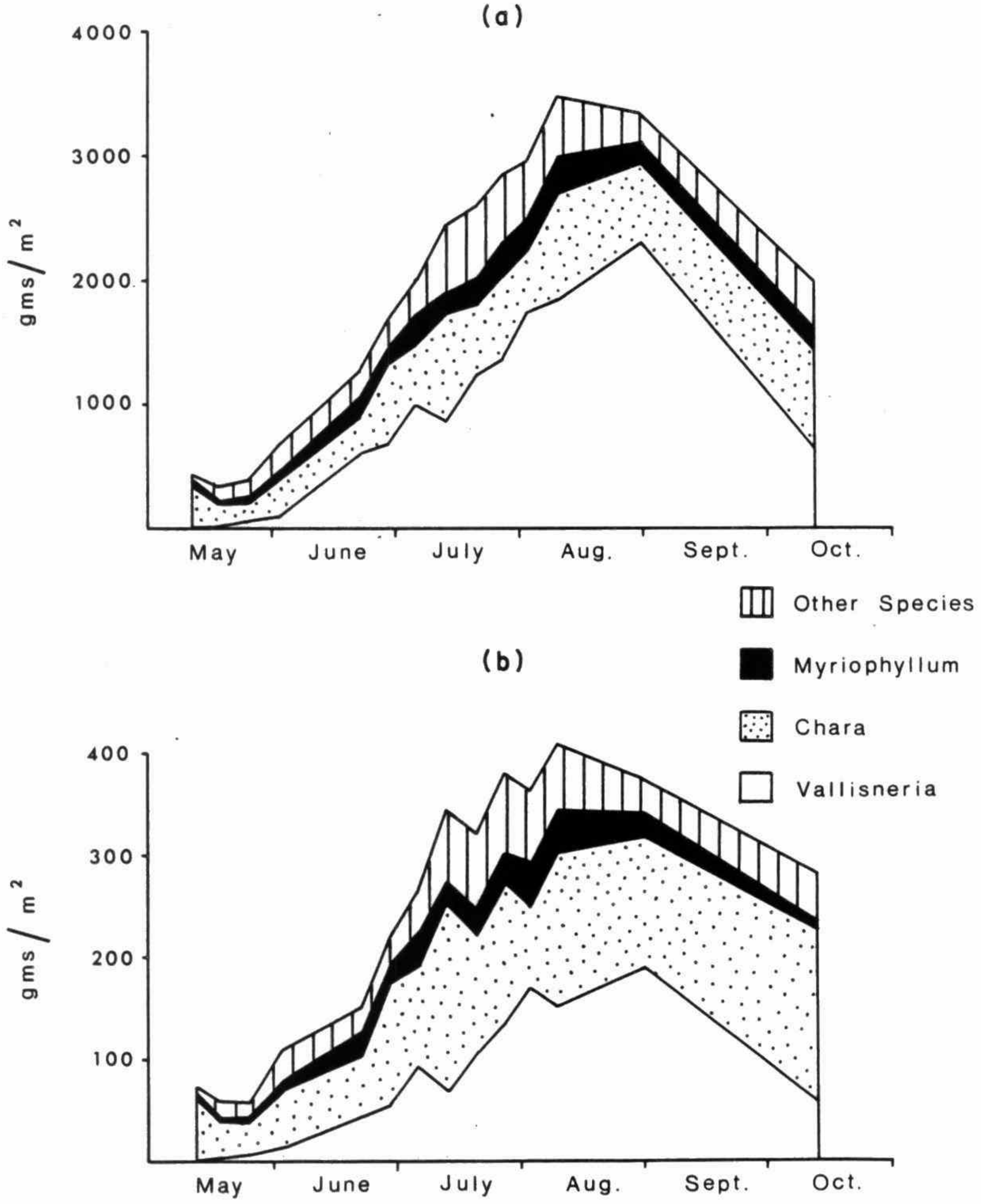

FIG. 10. Seasonal variations in macrophyte biomass in Chemung Lake in 1972; (a) wet weight, (b) dry weight.

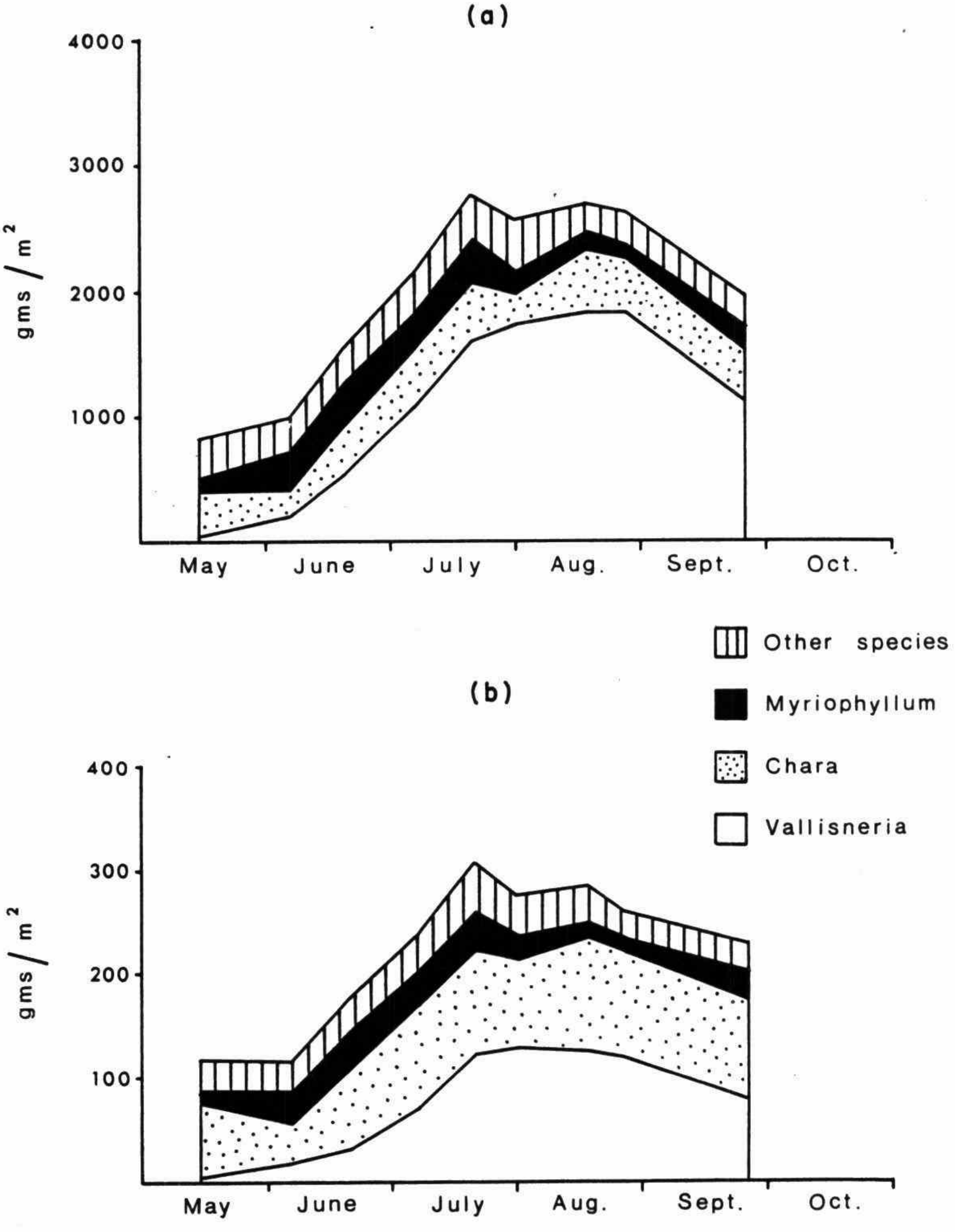

FIG. 11. Seasonal variations in macrophyte biomass in Chemung Lake in 1973; (a) wet weight, (b) dry weight.

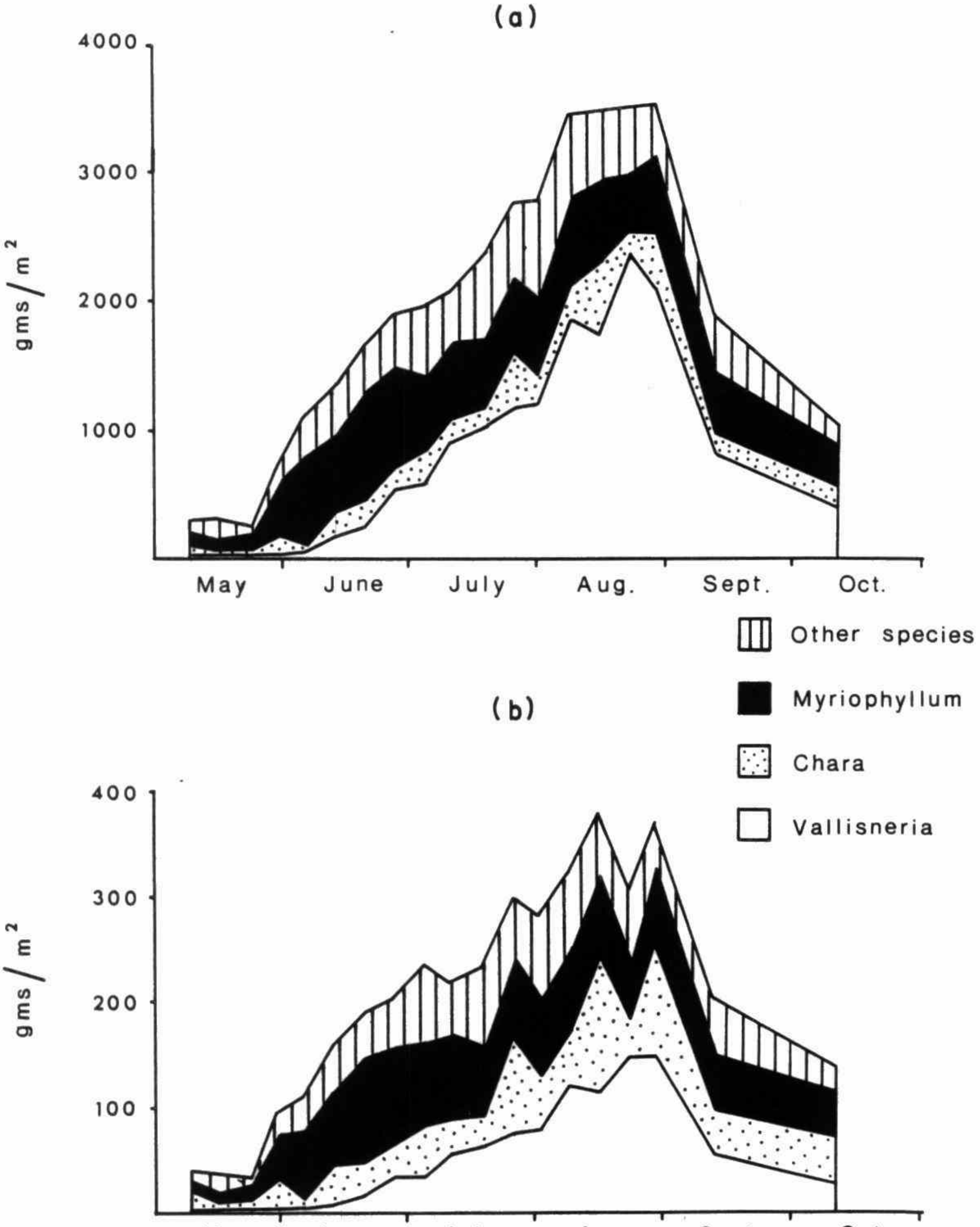

FIG. 12. Seasonal variations in macrophyte biomass in Chemung Lake in 1974; (a) wet weight, (b) dry weight.

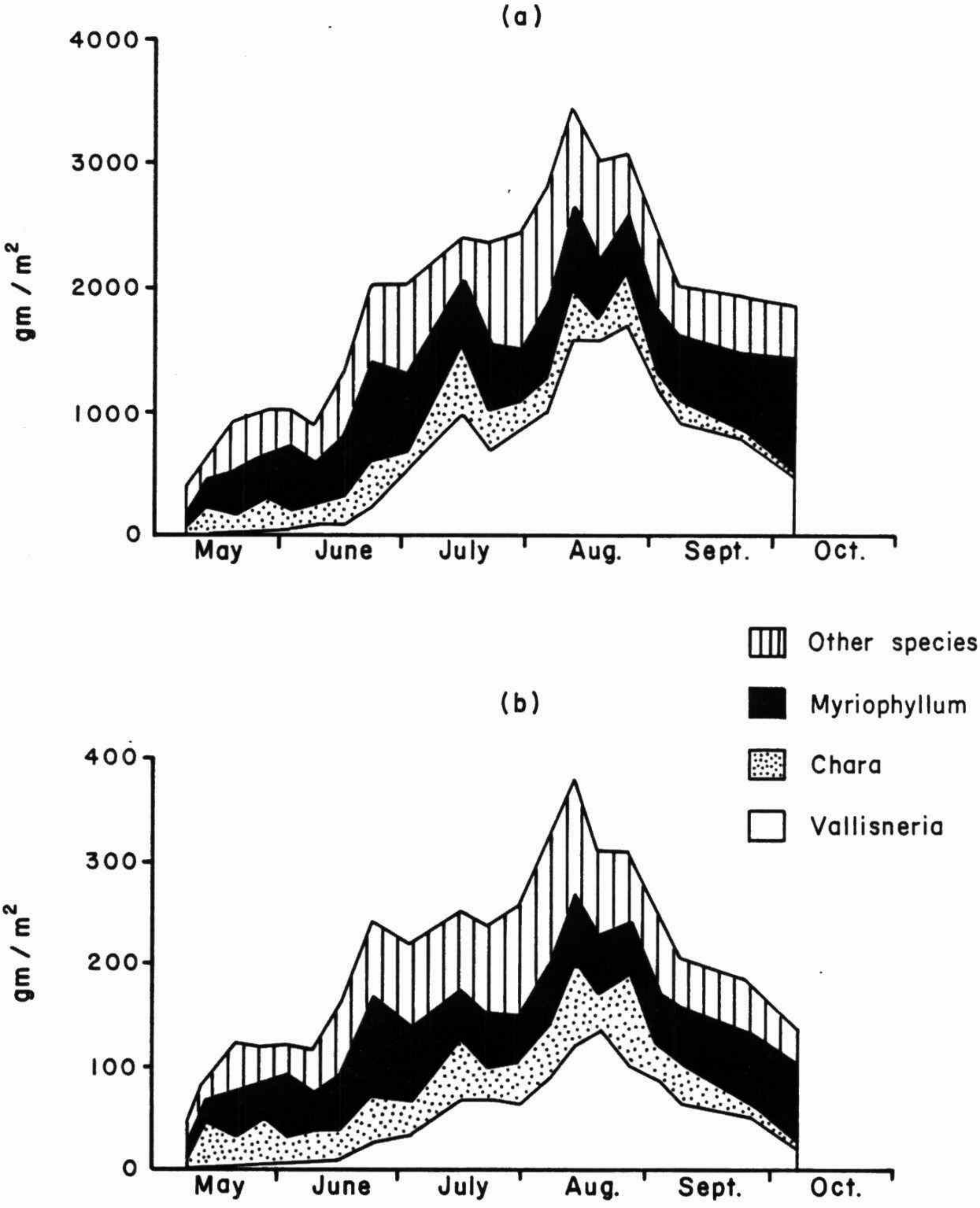

FIG. 13. Seasonal variations in macrophyte biomass in Chemung Lake in 1975; (a) wet weight, (b) dry weight.

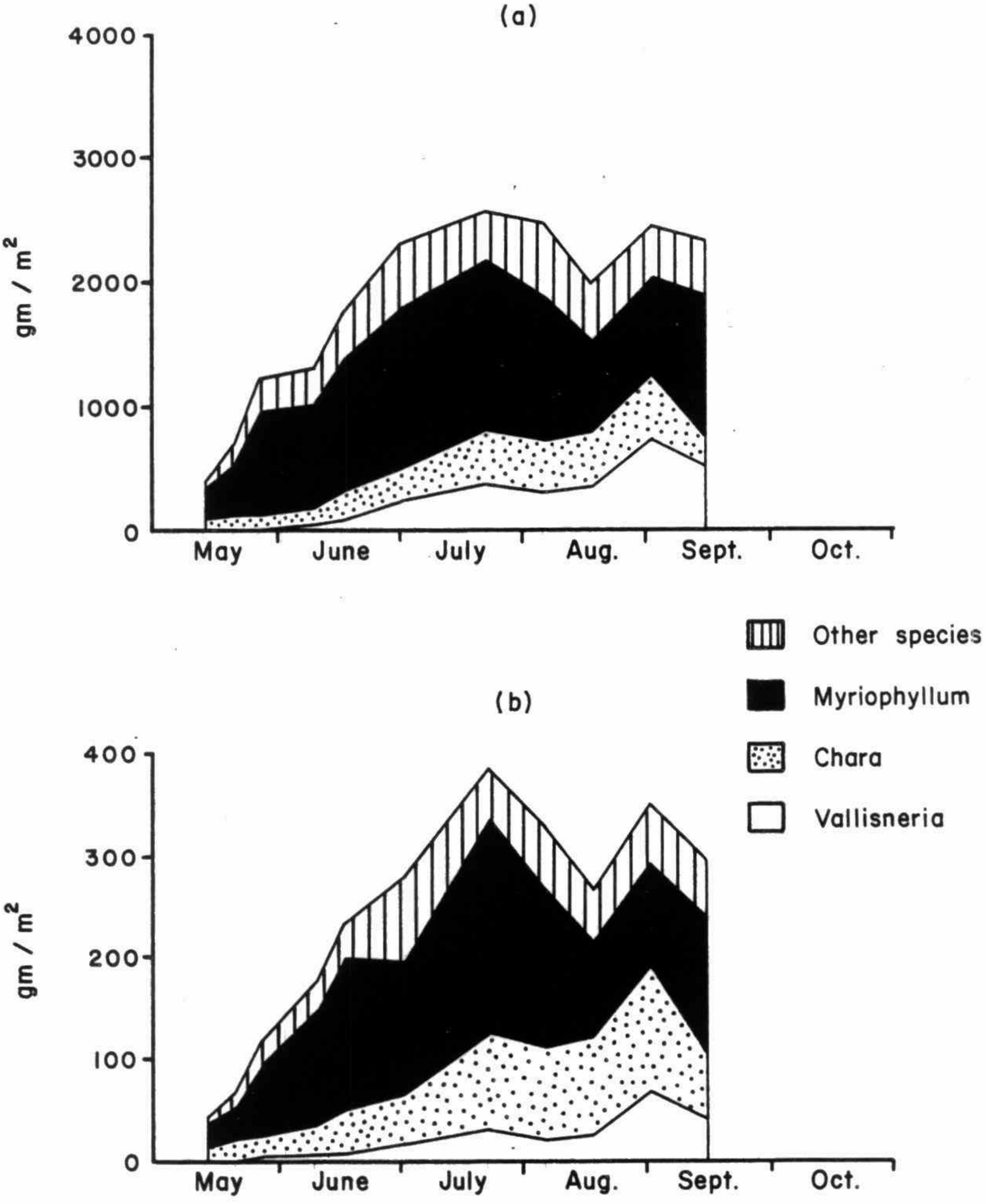

FIG. 14. Seasonal variations in macrophyte biomass in Chemung Lake in 1976; (a) wet weight, (b) dry weight.

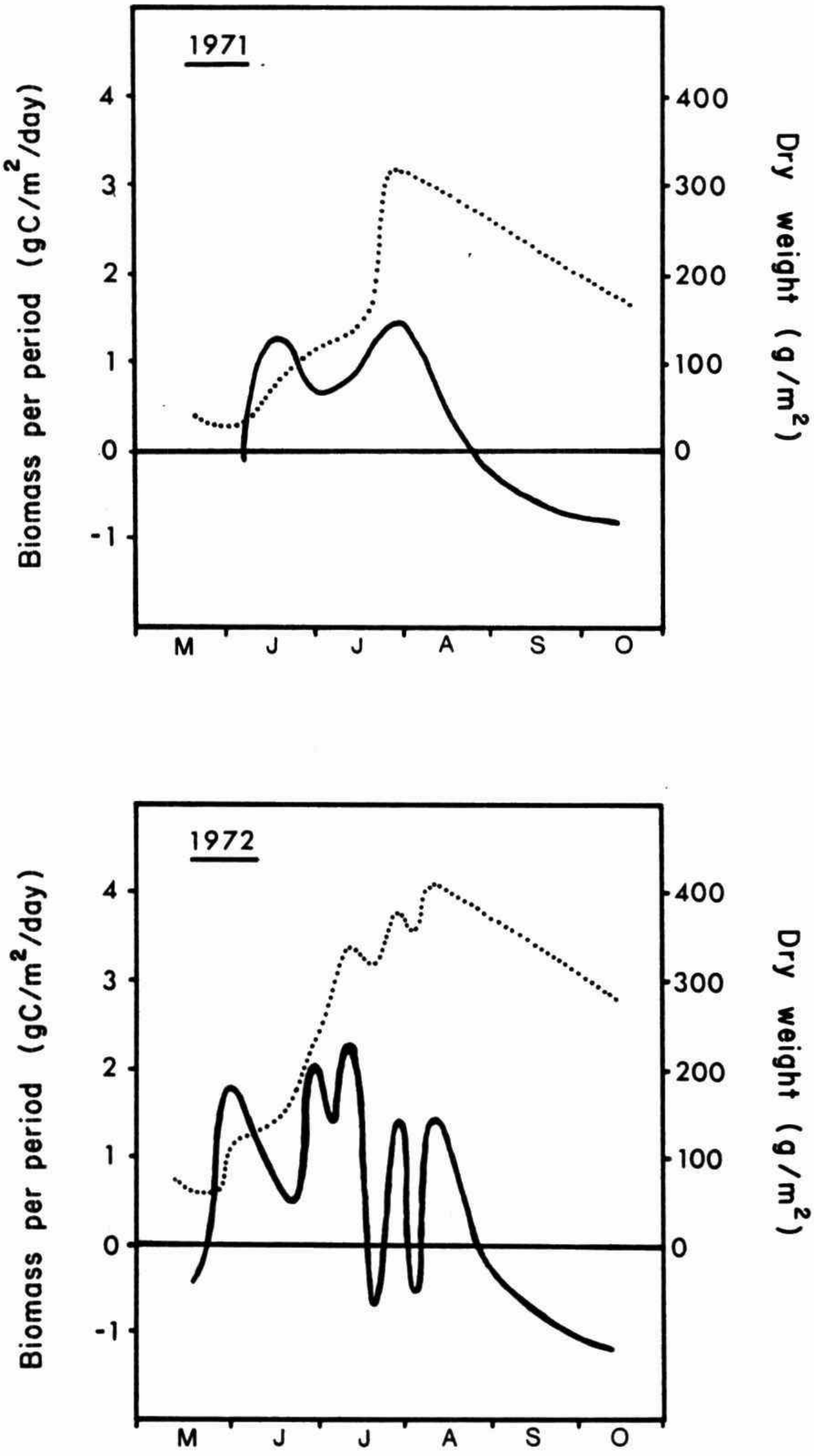

FIG. 15a. Seasonal changes in macrophyte biomass and productivity rates in southern Chemung Lake in 1971 and 1972; accumulative dry weight (·······), and biomass per time interval (——).

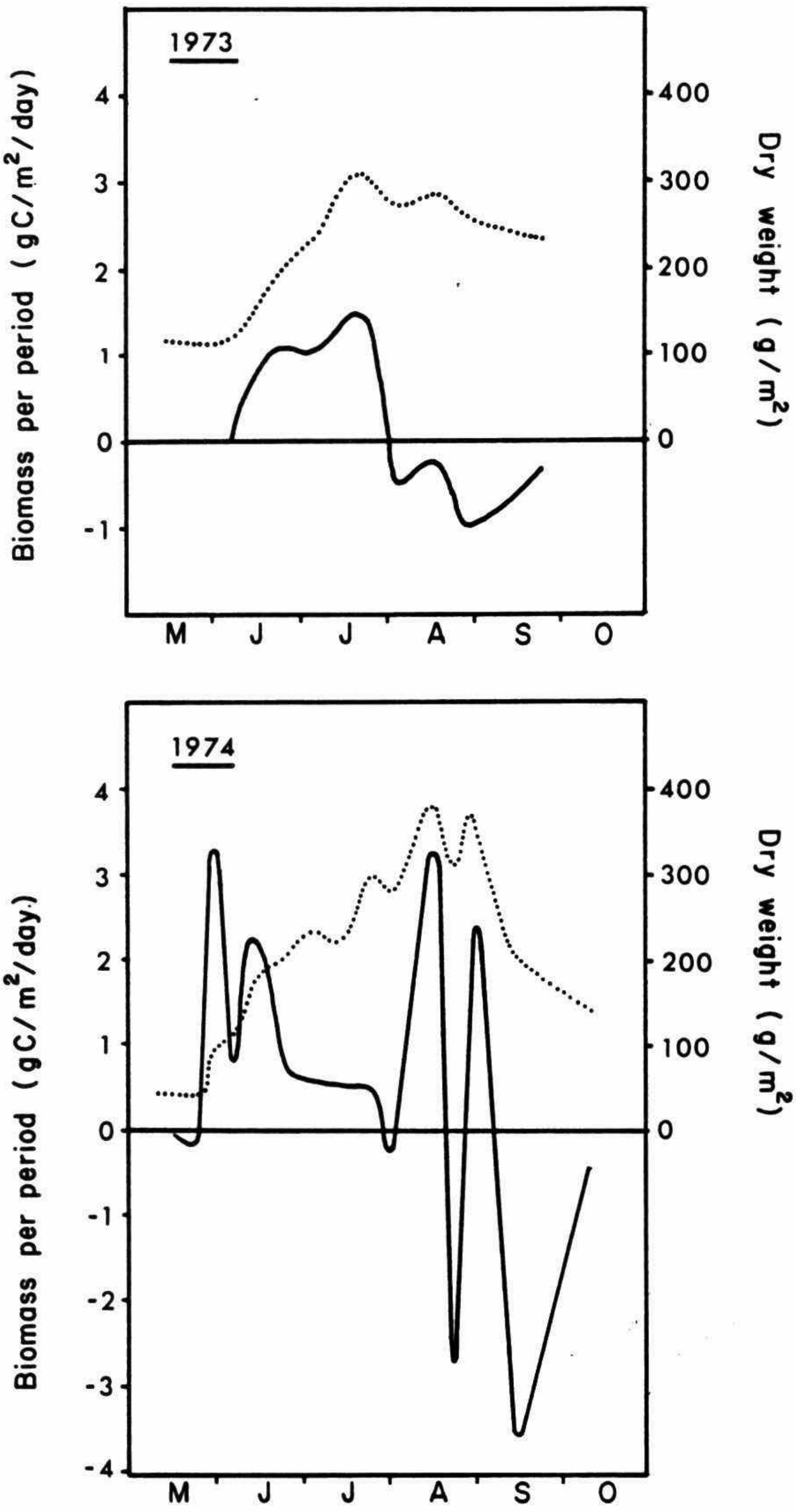

FIG. 15b. Seasonal changes in macrophyte biomass and productivity rates in southern Chemung Lake in 1973 and 1974; accumulative dry weight (······), and biomass per time interval (—).

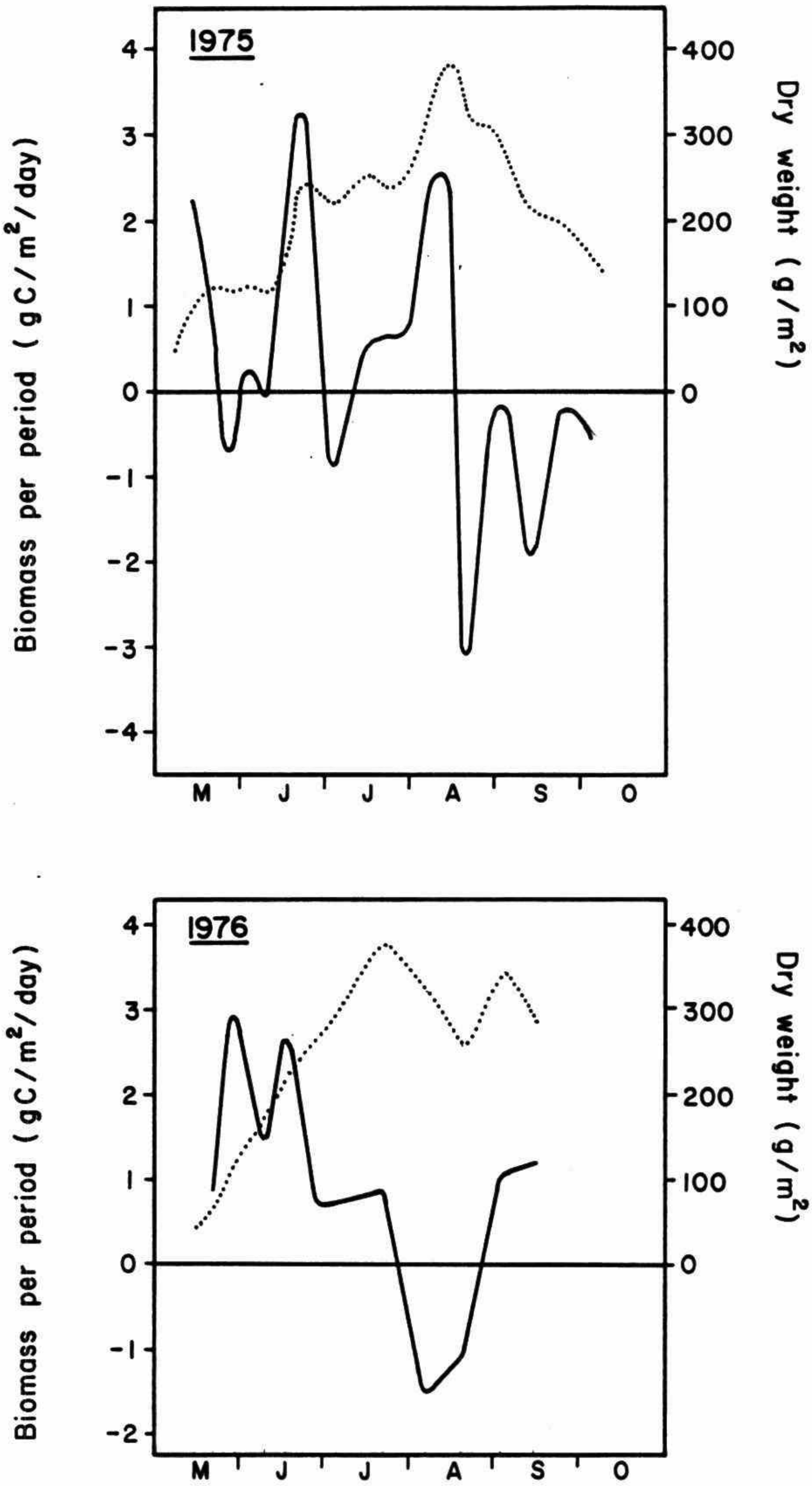

FIG. 15c. Seasonal changes in macrophyte biomass and productivity rates in southern Chemung Lake in 1975 and 1976; accumulative dry weight (······), and biomass per time interval (—).

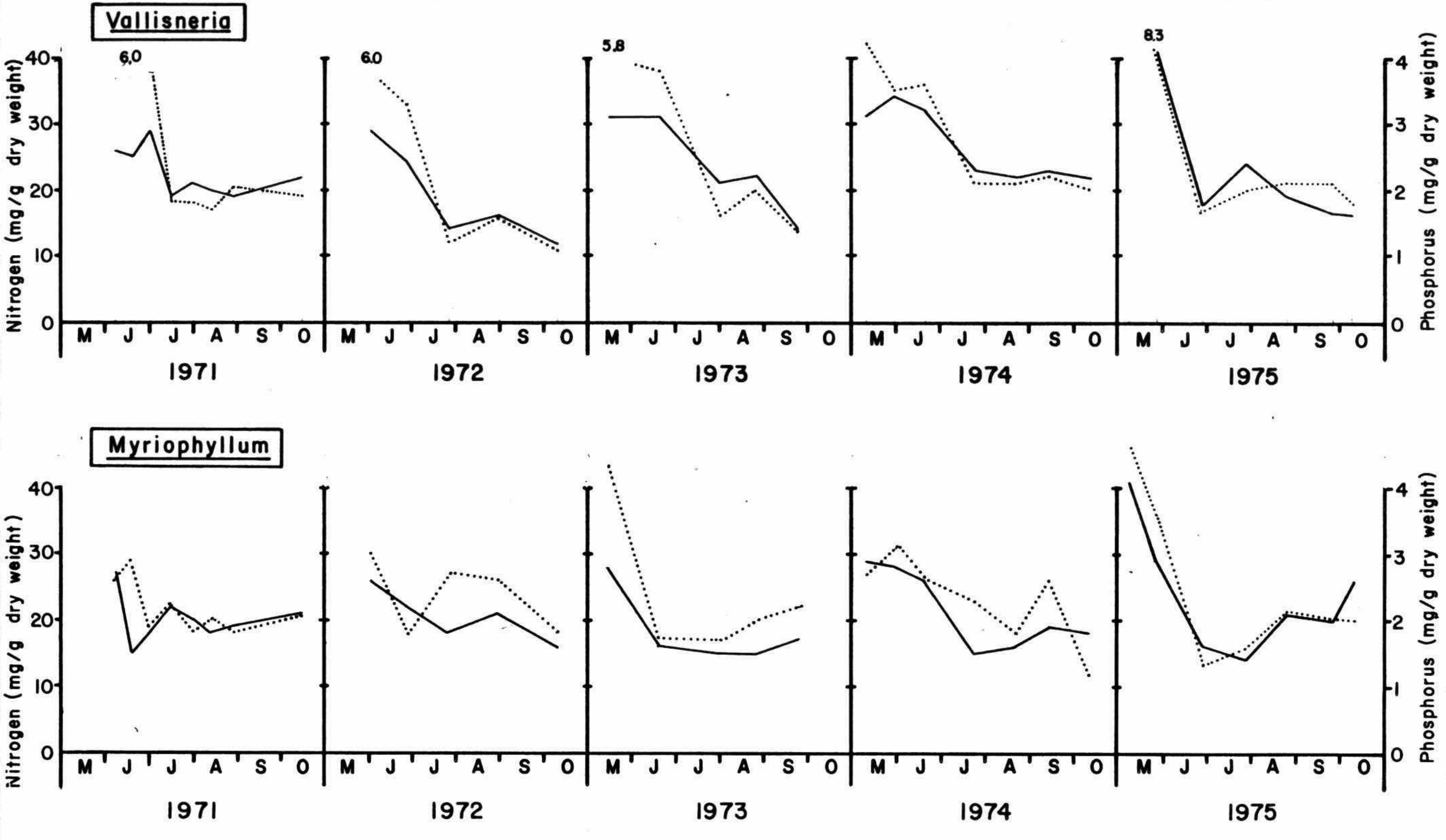

FIG. 16a. Seasonal variations in nitrogen and phosphorus levels (mg/g dry weight) in Vallisneria and Myriophyllum in Chemung Lake from May to October, 1971 to 1975. (— nitrogen, ------ phosphorus).

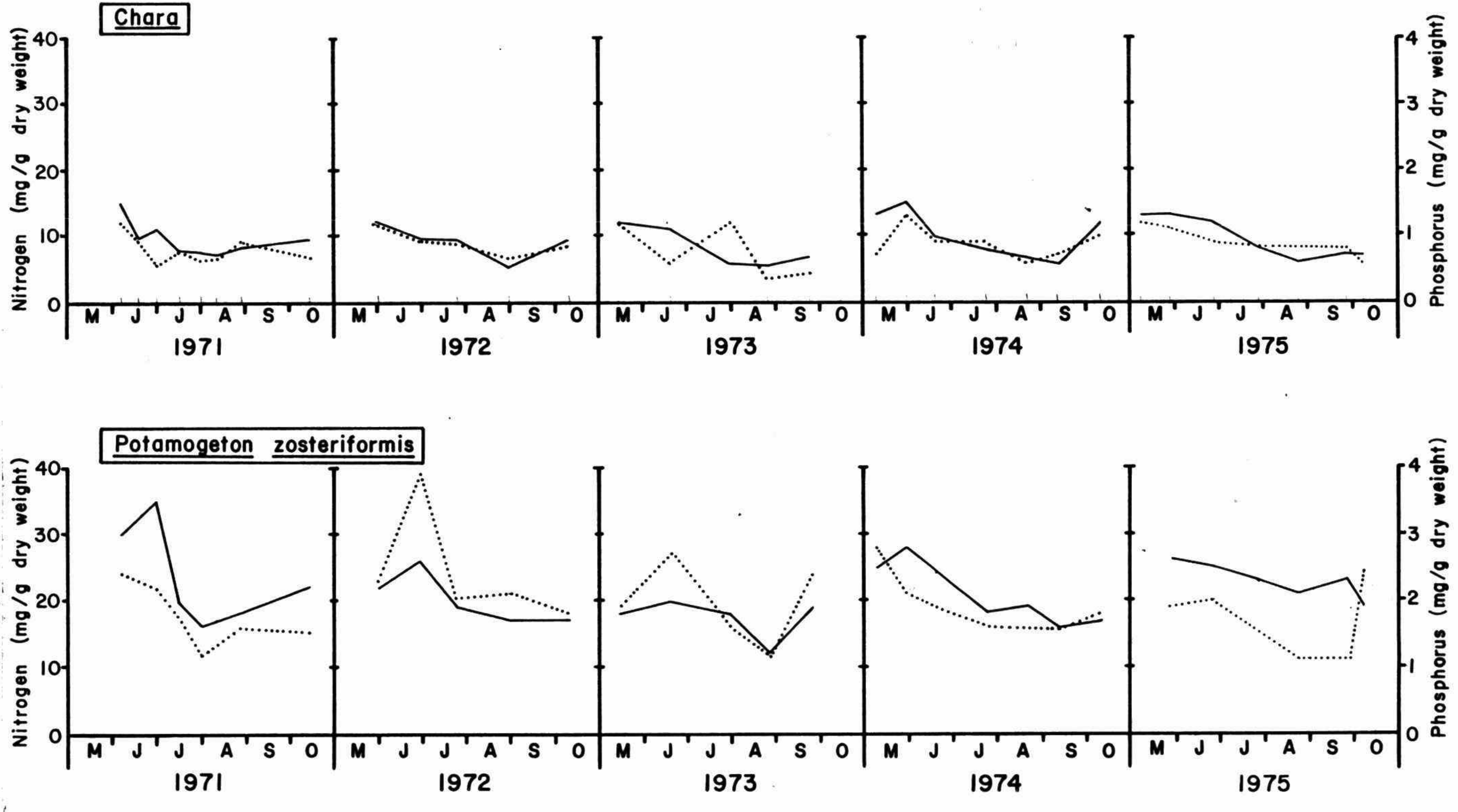

FIG. 16b. Seasonal variations in nitrogen and phosphorus levels (mg/g dry weight) in Chara and P. zosteriformis in Chemung Lake from May to October, 1971 to 1975. (—— nitrogen, ······· phosphorus).

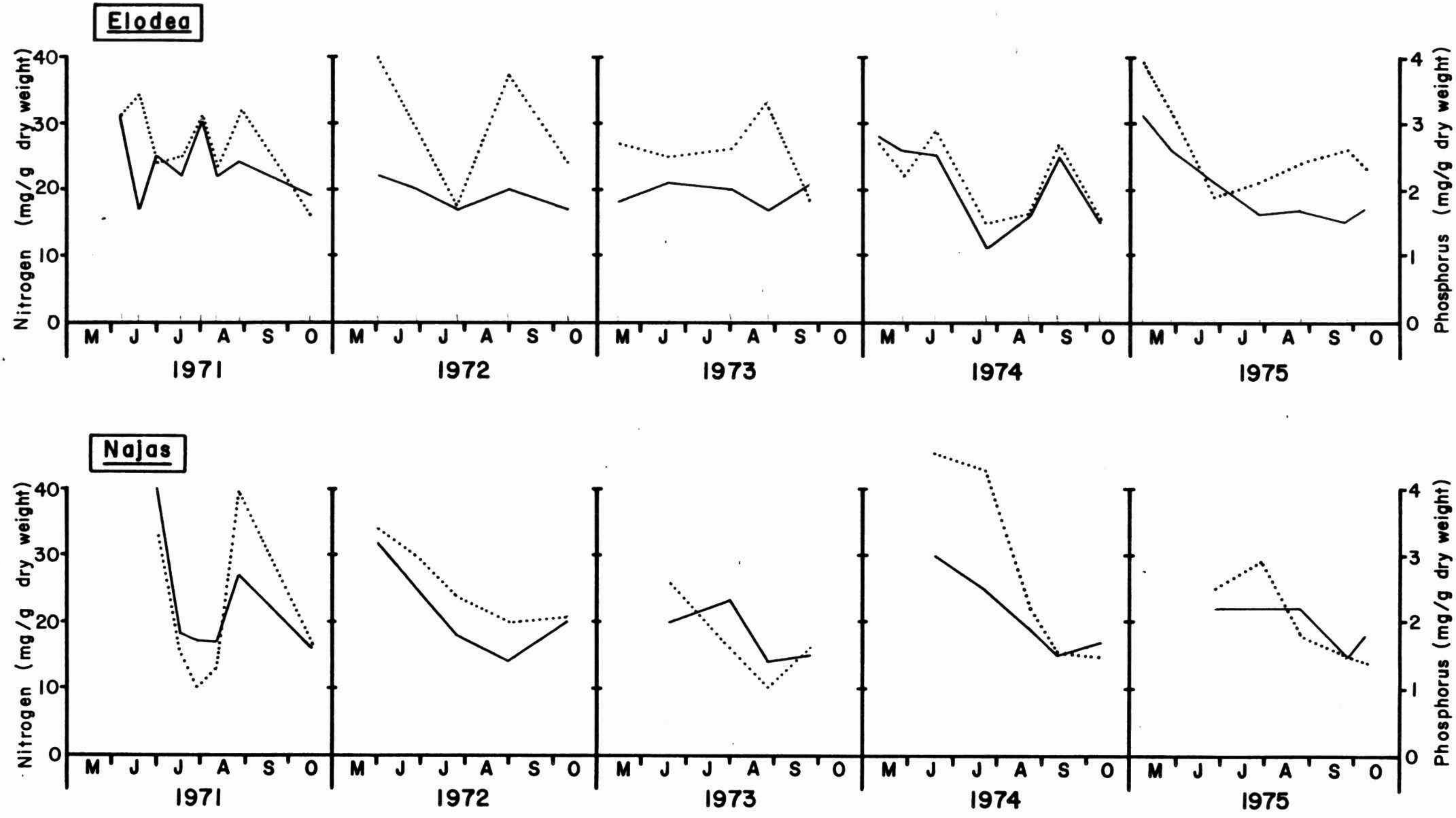

FIG. 16c. Seasonal variations in nitrogen and phosphorus levels (mg/g dry weight) in Elodea and Najas in Chemung Lake from May to October, 1971 to 1975. (— nitrogen, ······ phosphorus)

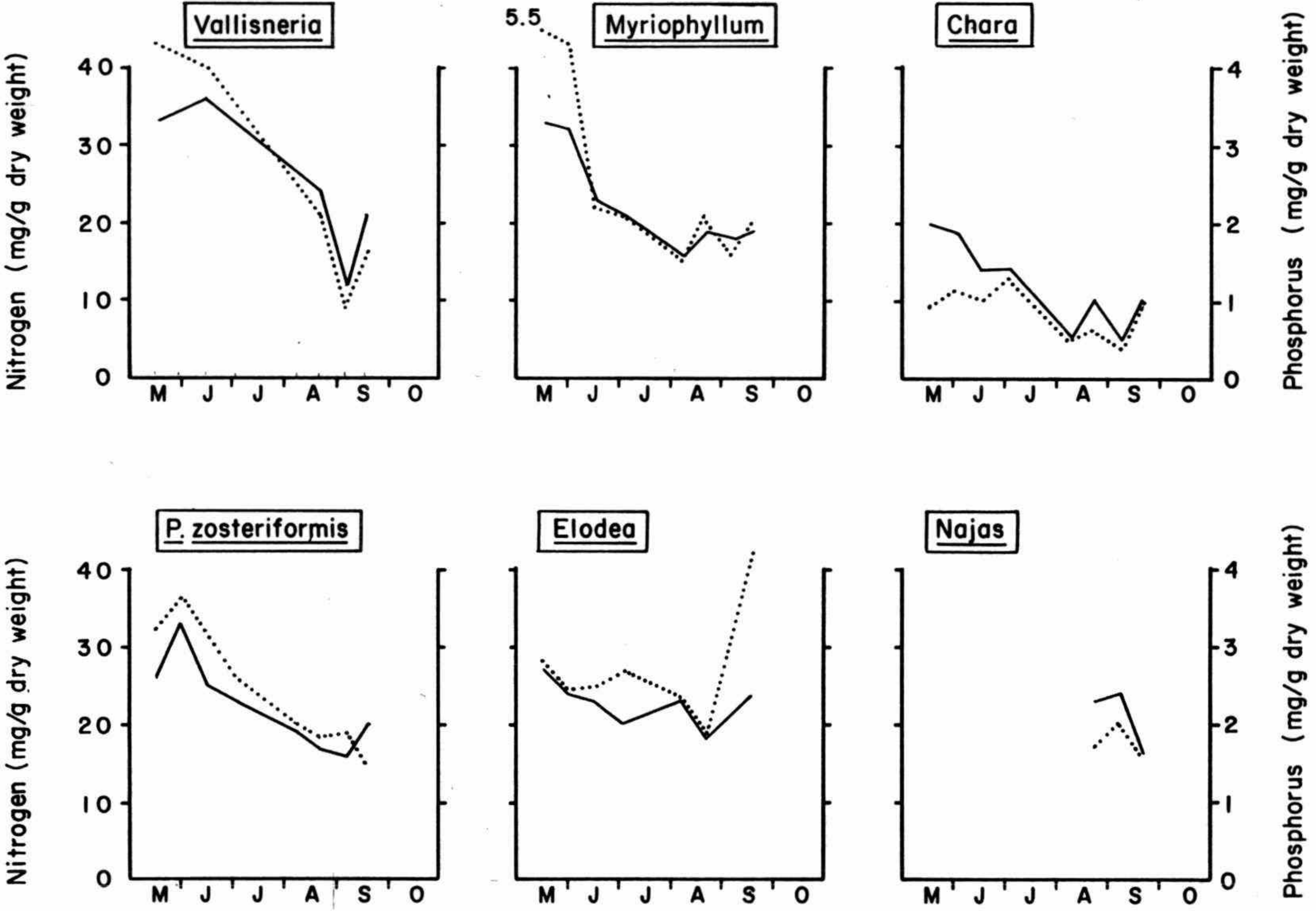

FIG. 16d. Seasonal variations in nitrogen and phosphorus levels (mg/g dry weight) in Chemung Lake macrophytes from May to October, 1976.

CHAPTER 7

THE EFFECT OF HARVESTING ON PLANT GROWTH IN EXPERIMENTAL PLOTS IN CHEMUNG LAKE

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8. Percentage change in average plant height after initial June sampling, at experimental flower pots cut 12" above sediment in Chemung Lake in 1976.

9. Percentage change in stem numbers after initial June sampling, at experimental flower pots cut 6" above sediment, in Chemung Lake in 1976.

10. Percentage change in stem numbers after initial June sampling, at experimental flower pots cut at 12" above sediment, in Chemung Lake in 1976.

11. Mean annual plant biomass at a harvested and adjacent non-harvested site in southern Chemung Lake.

INTRODUCTION

Mechanical harvesting of aquatic vegetation has been advocated as an environmentally sound control measure, although some concern has been expressed about rates of regrowth and potential increases in plant densities following application of this technique.

The present study was designed to evaluate the effects of single and multiple harvests, timing of the harvesting and depth of harvesting on stem densities and rates of regrowth of *M. spicatum* L.

METHODS

Experimental plots were established in a pure stand of *Myriophyllum spicatum*, situated near the north-east shore of southern Chemung Lake in water depths of 2 to 2.5 m. Establishment of the experimental plots was completed in early May, when growth was relatively light, thereby avoiding any unnecessary physical disruption of the plants. Wooden quadrats, enclosing 0.25 m^2 were positioned over the plants and carefully anchored into the sediment. Plants immediately adjacent to each quadrat were removed to allow sufficient light penetration to the selected plot. Two quadrats served as controls and were allowed to grow uninterrupted all season. The remaining quadrats were harvested at different times during the summer to provide the following treatments:

a) a single harvest per season in either June, July or August
b) two harvests per season in either June and July, June and August, and July and August
c) three harvests per season in June, July and August

Plants were harvested 20 centimeters above the sediment by a scuba diver using a pair of sheers. Prior to harvesting, the plant density (number of stems) and average plant height were determined for each quadrat. Average plant height was determined by grouping stems into the following categories: 15 cm or less, 15 to 30 cm and in 30 cm intervals thereafter. The results of the harvesting treatments were expressed as a percentage change in stem numbers and average plant height from pretreatment levels. The experiments were started in 1975 and repeated in 1976.

A second experiment was performed in 1976 to assess the effects of varying the depth of cut on plant regrowth. Fifteen cm clay pots mounted on a plywood frame were secured on the lake bottom in the middle of a cleared milfoil bed. Plants consisting of approximately fifteen to thirty individual shoots were transplanted into the flower pots. The roots were tucked into the pots with as little disturbance as possible and covered with sediment. After several weeks of acclimation, these plants were subjected to harvests at different times similar to those previously described, with the exception that one half were cut 15 cm above the sediment and the other half were cut 30 cm above the sediment. Average plant height and stem numbers were determined prior to each treatment and results were expressed as previously described.

RESULTS

Several problems arose with the 1976 experiments. All the potted plants as well as many plants in the area appeared unhealthy and lacked fresh green growth. A disease specific to milfoil, such as Northeast disease or Lake Venice disease (Bayley, 1970) was considered a possibility, however, extract from unhealthy plants failed to produce disease symptoms when inoculated into healthy plants. Physical disruption, confined root space, or some unidentified environmental stress may have contributed to the plants unhealthy condition. For this reason, the 1976 data on the potted plants is of limited value and discussion shall be mostly limited to the 1975 and 1976 experiments involving undisturbed healthy plants.

Figures 1 and 2 illustrate the percentage change in the number of stems throughout the season in the experimental plots in 1975 and 1976. Control plots exhibited increases in stem numbers greater than 200% between June to October in both years. All harvested plots, regardless of the month of the cut, had smaller increments (less than 150%) or reductions over original numbers. The results of the single harvests were inconsistent, with reduced stem numbers apparent for one to three months after harvesting. The multiple cuts were most effective in reducing the stem numbers for a longer period of time.

Changes in plant heights (monitored on a monthly basis only in 1976) are summarized in Table 1. Rates of regrowth were quite variable ranging between one to three months in the case of single harvest plots.

Table 1. Changes in average plant height (meters) at experimental harvesting plots in Chemung Lake in 1976.

Cutting Month	June23	July22	Aug.20	Sept.16	Oct.5	as a % of control in October
control	1.10	1.25	1.68	1.52	1.62	100
June cut	-	0.43	0.67	0.58	0.49	30
July cut	-	1.49	0.30	0.70	0.76	49
August cut	-	-	1.28	0.34	0.58	36
June-July cut	-	0.40	0.15	0.55	0.52	32
June-Aug. cut	-	0.37	0.37	0.30	0.27	17
July-Aug. cut	-	-	0.34	0.27	0.40	25
June-July-Aug. cut	-	0.52	0.15	0.27	0.27	17

Greatest reductions in plant heights during the latter part of the season were apparent in the multiple harvest plots that included both a June and August cut.

Figures 7, 8, 9, 10 illustrate the effect of varying the depth of cut on plant densities and rates of regrowth. Harvesting the plants 15 cm above the sediment was more effective in reducing both stem numbers and stem heights than harvesting at a depth of 30 cm above the sediment.

DISCUSSION

The effectiveness of the harvesting technique in maintaining an unobstructed water column by simultaneously reducing both plant stem heights and densities appears to be dependent on the time of year selected for cutting, the number of cuttings per season and the depth of the cut. Early season (June, July) single harvests were the least effective in reducing plant densities and rates of regrowth for an extended period of time, while three harvests per season achieved maximum reductions. As illustrated in figures 3 to 6 two harvests per season, which include an August cut, were also highly effective in simultaneously reducing both stems numbers and stem heights. In a similar study Nichols and Cottam (1972) found that a single harvest reduced plant growth by 50%, two harvests reduced it by 75% and three harvests virtually eliminated plant material for the year. Their studies also showed that harvesting one year reduced plant biomass the following year, especially in deeper waters. This reduction in plant biomass was not apparent following a single year of harvesting in the present study, perhaps due to the fact that the invasion of Eurasian water milfoil coincided with the harvesting program. However, visual observations of the areas of the lake which had been harvested for three successive years indicated that the plants were considerably slower in reaching the water surface. Similarily, mean annual plant biomass at a harvested site located along the east shore of southern Chemung Lake was considerably reduced following three successive years of harvesting when compared to an adjacent non-harvested site (Figure 11).

Although studies on the effects of the depth of cut on potted milfoil plants were rather inconclusive due to the onset of "disease like" conditions, the data suggest a longer control period can be achieved when the plants are cut closer to the sediment. Visual observations by scuba divers in areas cut with the large harvester confirm this affect. Many of the harvested stems cut below the leafy portion of the stem died or showed minimal growth for the remainder of the season. When the depth of cut was above the start of the leafy portion of the stem, fewer stems died and regrowth was much faster. New stems generally sprouted from the first node below the cutting plane and many younger stems which remained intact rapidly reached the water surface.

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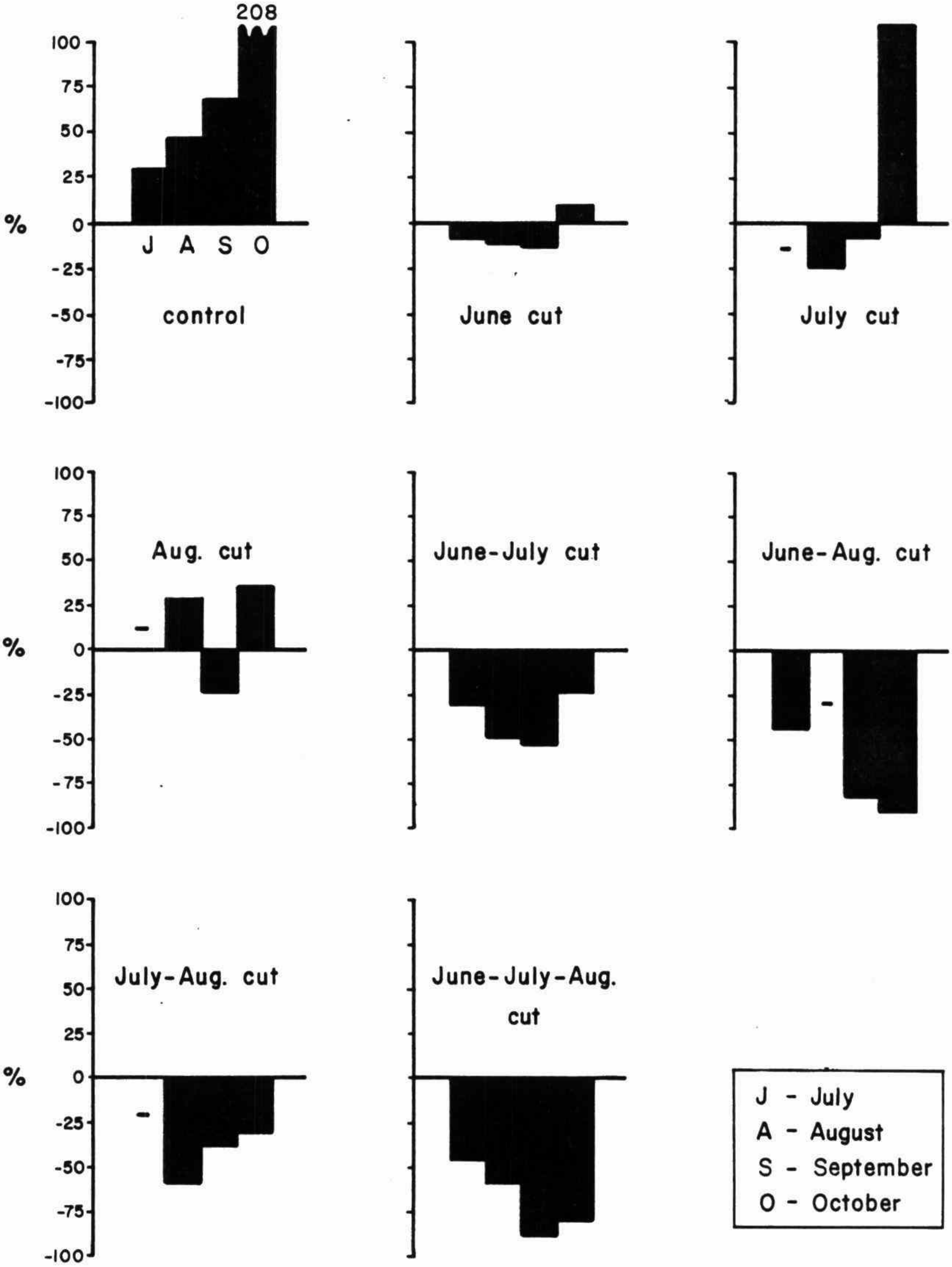

FIG. I. Percentage change in stem numbers after initial June sampling, at experimental cutting plot for *Myriophyllum* in Chemung Lake in 1975.

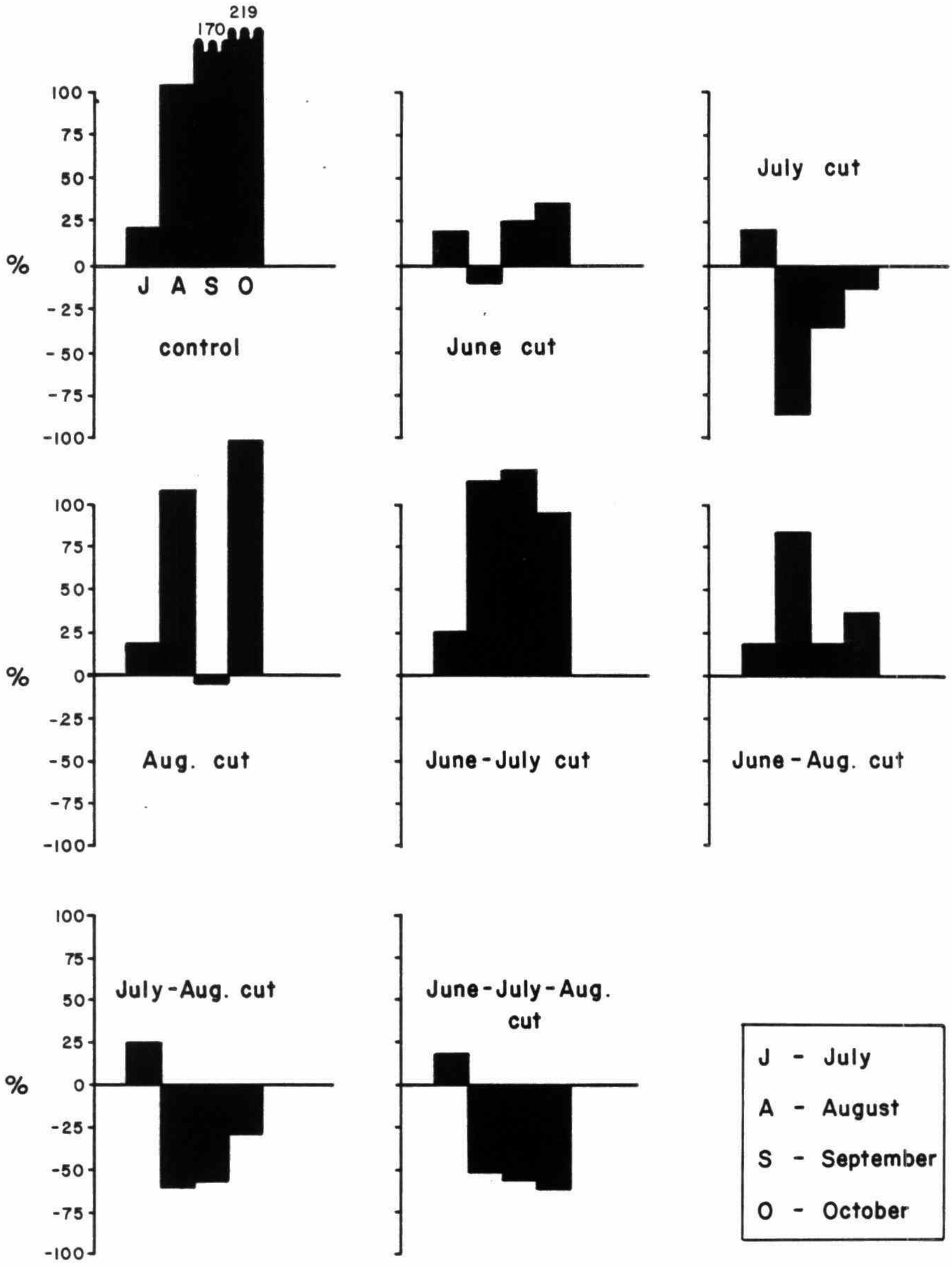

FIG. 2. Percentage change in stem numbers after initial June sampling, at experimental cutting plot for *Myriophyllum* in Chemung Lake in 1976.

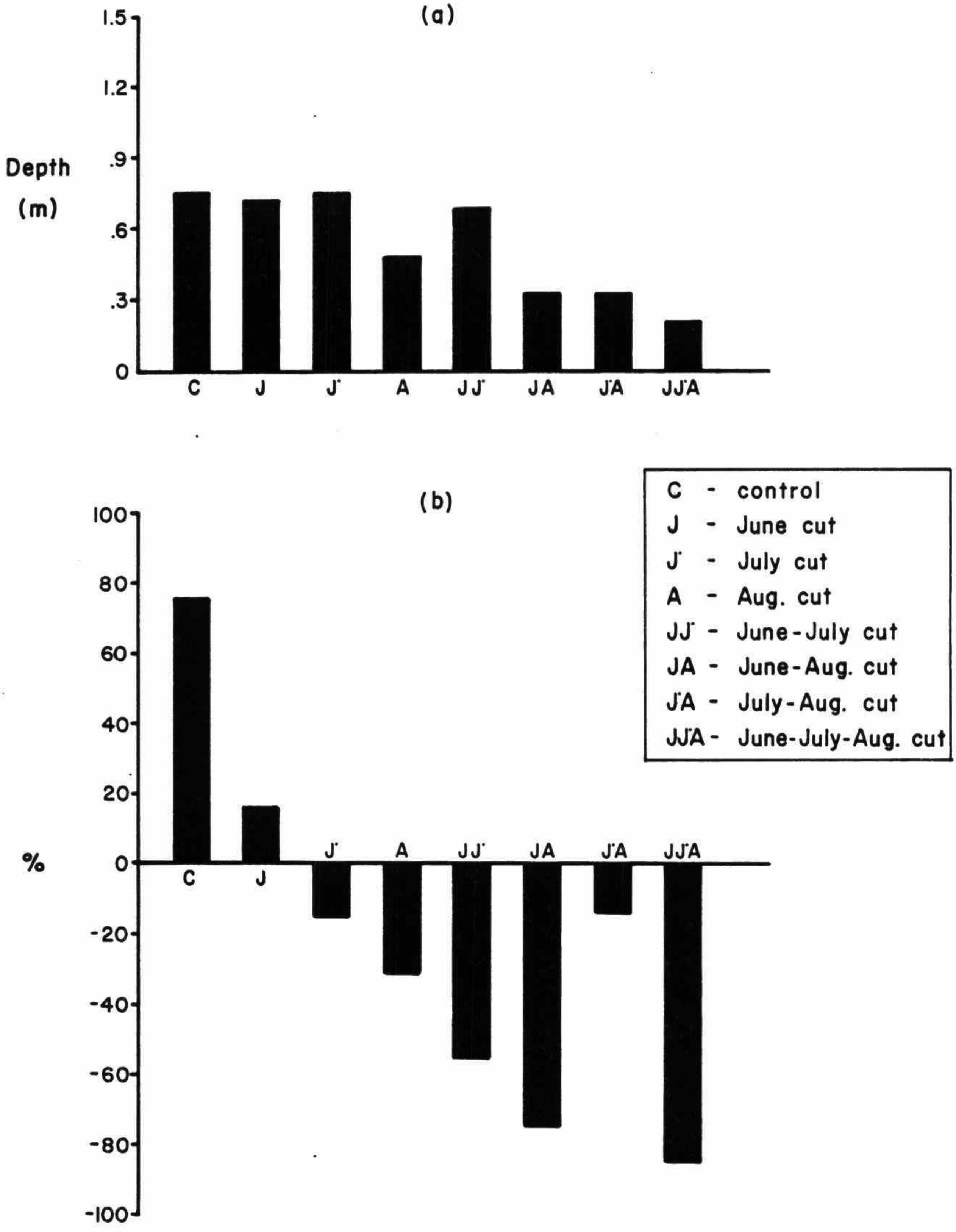

FIG. 3. (a) Average plant height in *Myriophyllum* experimental cutting plot in Chemung Lake by September 1975, compared to (b) percentage change in stem numbers after initial June sampling.

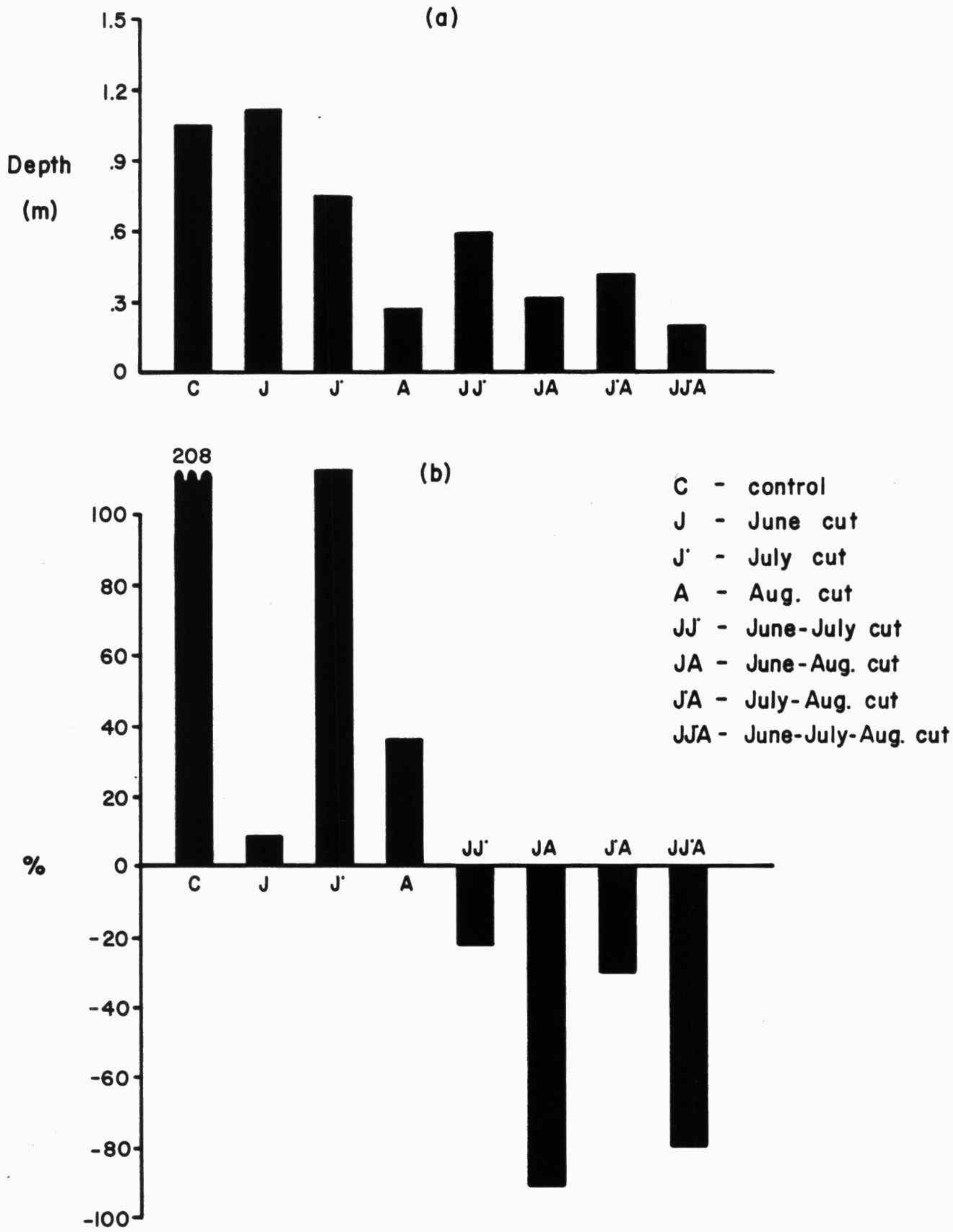

FIG. 4. (a) Average plant height in Myriophyllum experimental cutting plot in Chemung Lake by October 1975, compared to (b) the percentage change in stem numbers after initial June sampling.

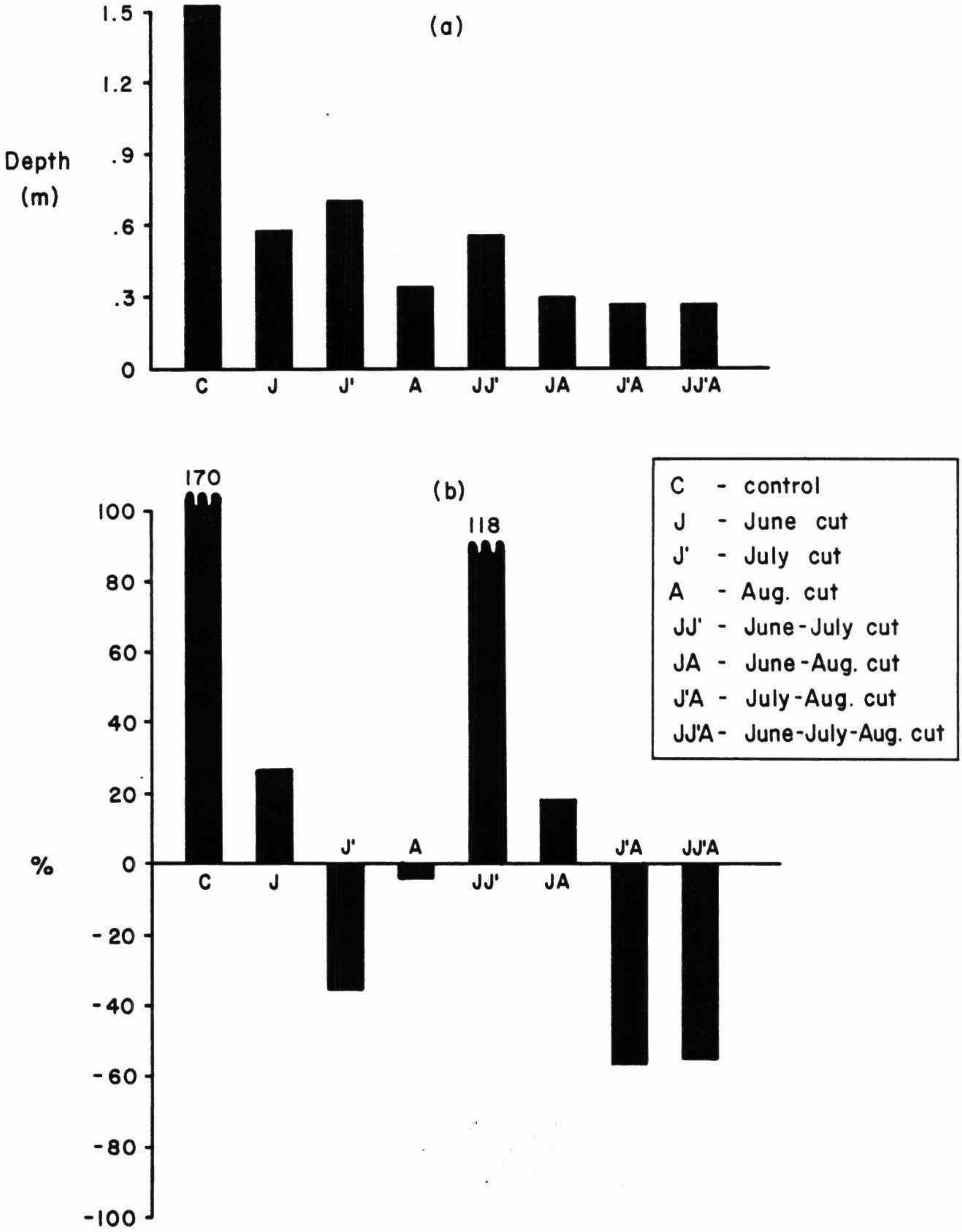

FIG. 5. (a) Average plant height in Myriophyllum experimental cutting plot in Chemung Lake by September 1976, compared to (b) percentage change in stem numbers after initial June sampling.

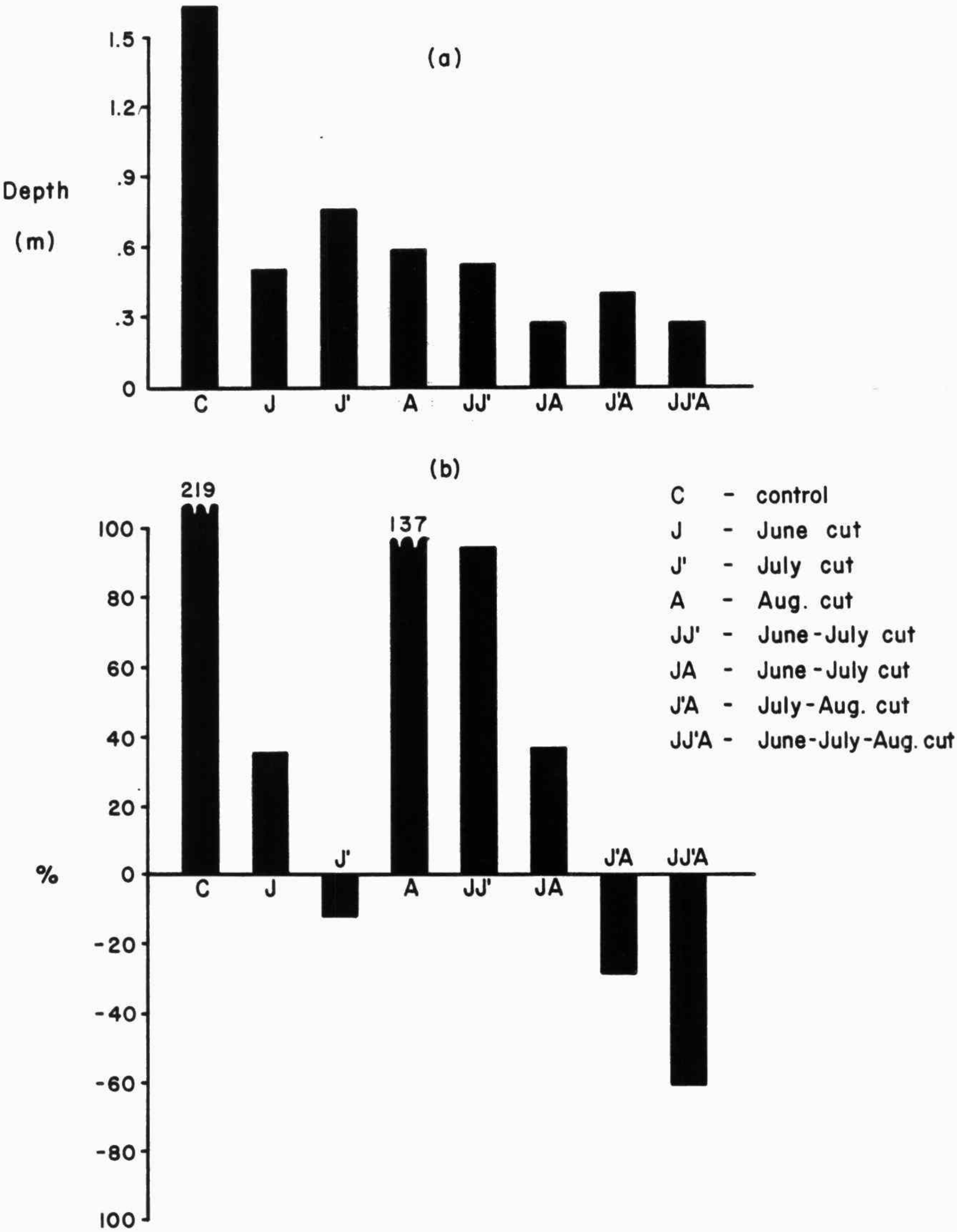

FIG. 6. (a) Average plant height in Myriophyllum experimental cutting plot in Chemung Lake by October 1976, compared to (b) percentage change in stem numbers after initial June sampling.

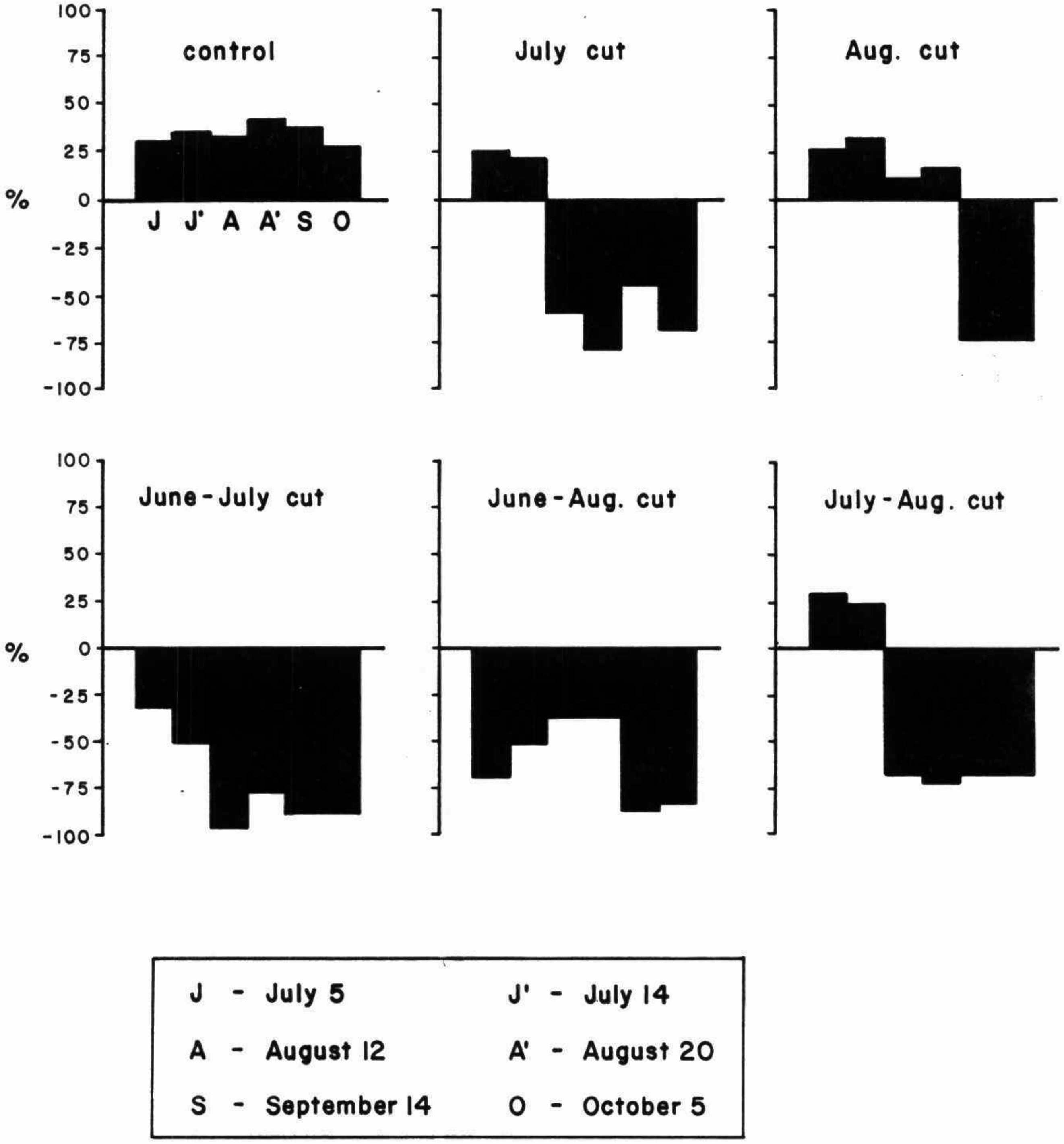

FIG. 7. Percentage change in stem numbers after initial June sampling, at experimental flower pots cut at 6" above sediment, in Chemung Lake in 1976.

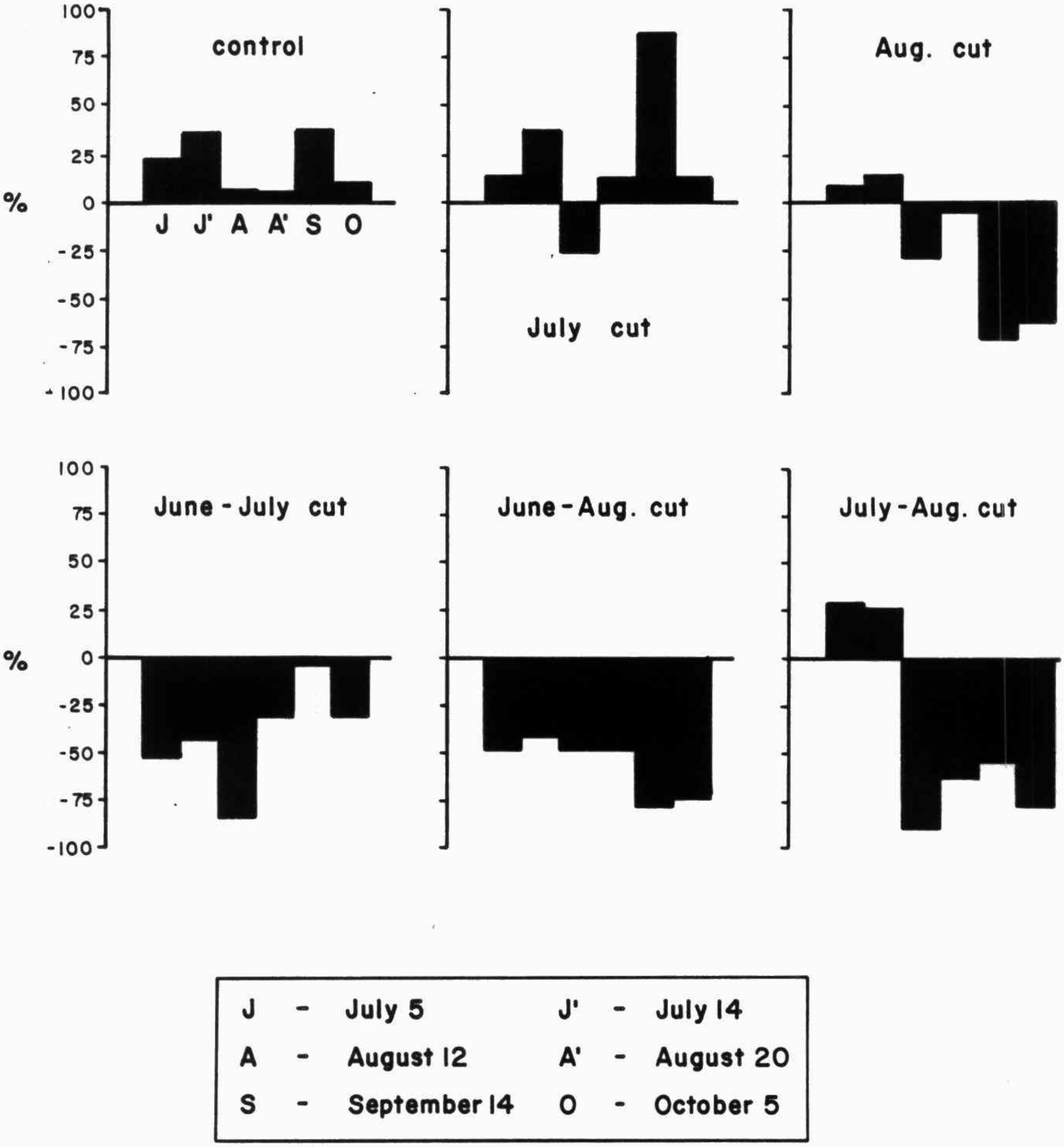

FIG. 8. Percentage change in stem numbers after initial June sampling, at experimental flower pots cut at 12" above sediment, in Chemung Lake in 1976

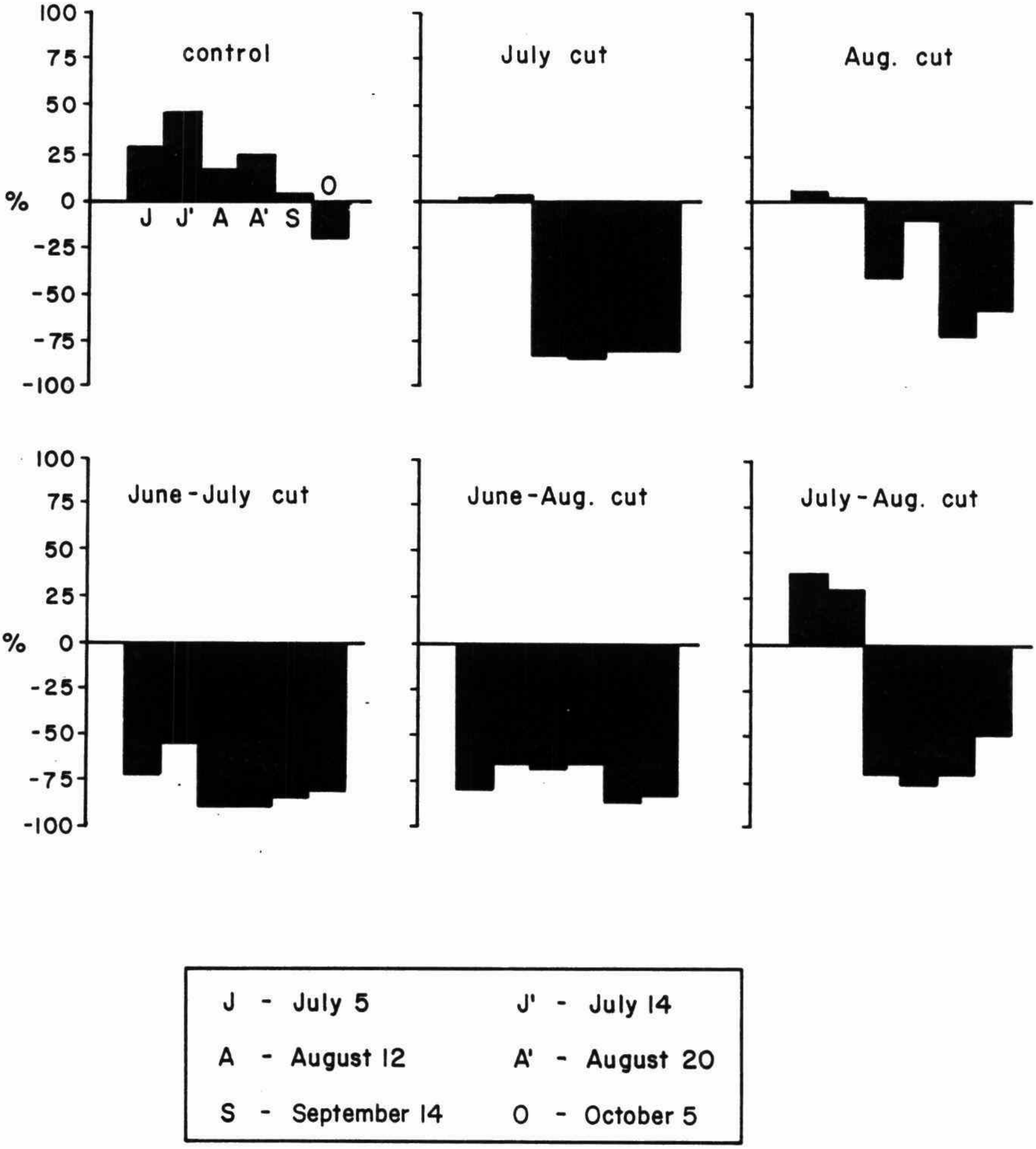

FIG. 9. Percentage change in average plant height after initial June sampling, at experimental flower pots cut 6" above sediment, in Chemung Lake in 1976.

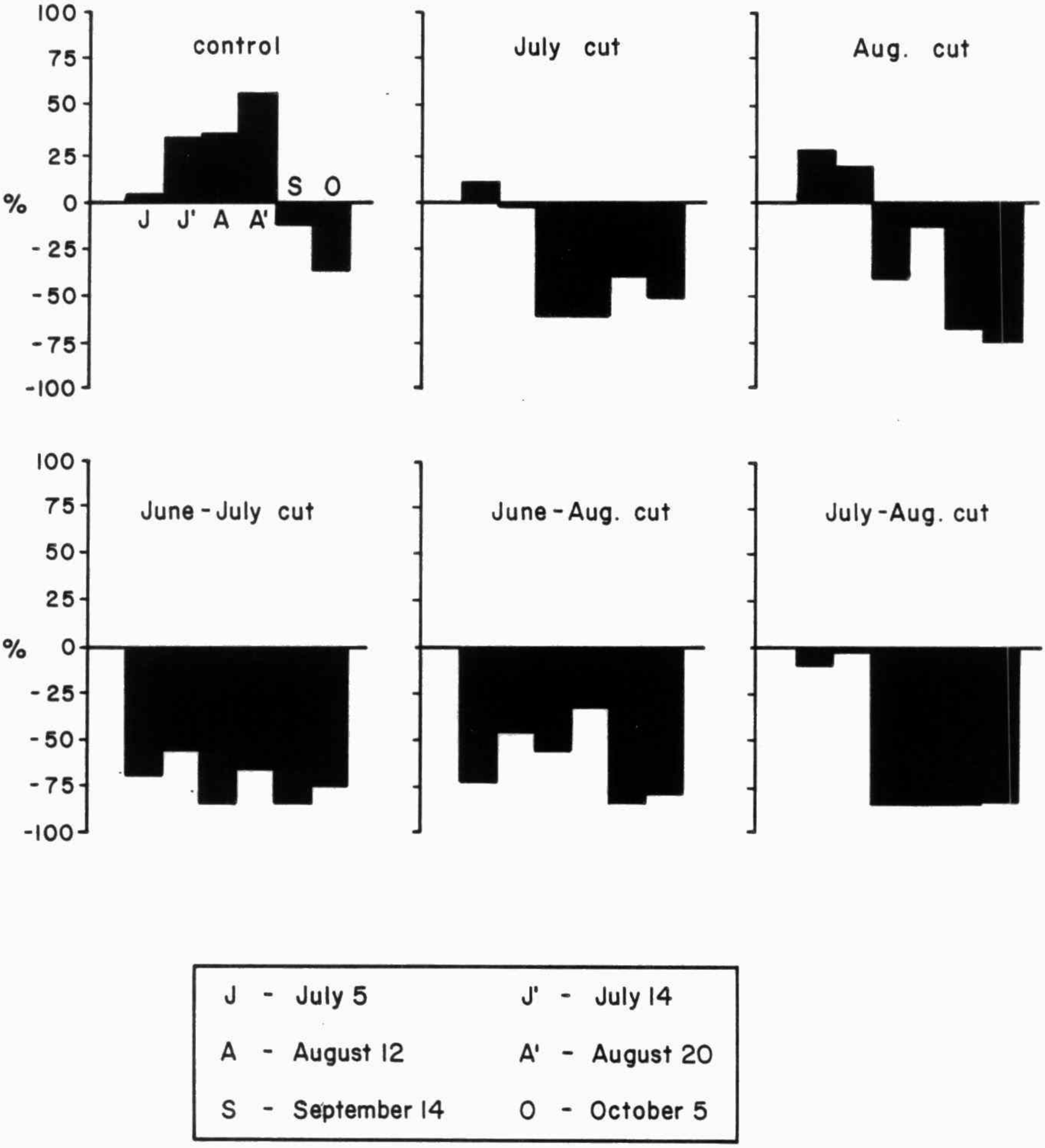

FIG. 10. Percentage change in average plant height after initial June sampling, at experimental flower pots cut at 12" above sediment, in Chemung Lake in 1976.

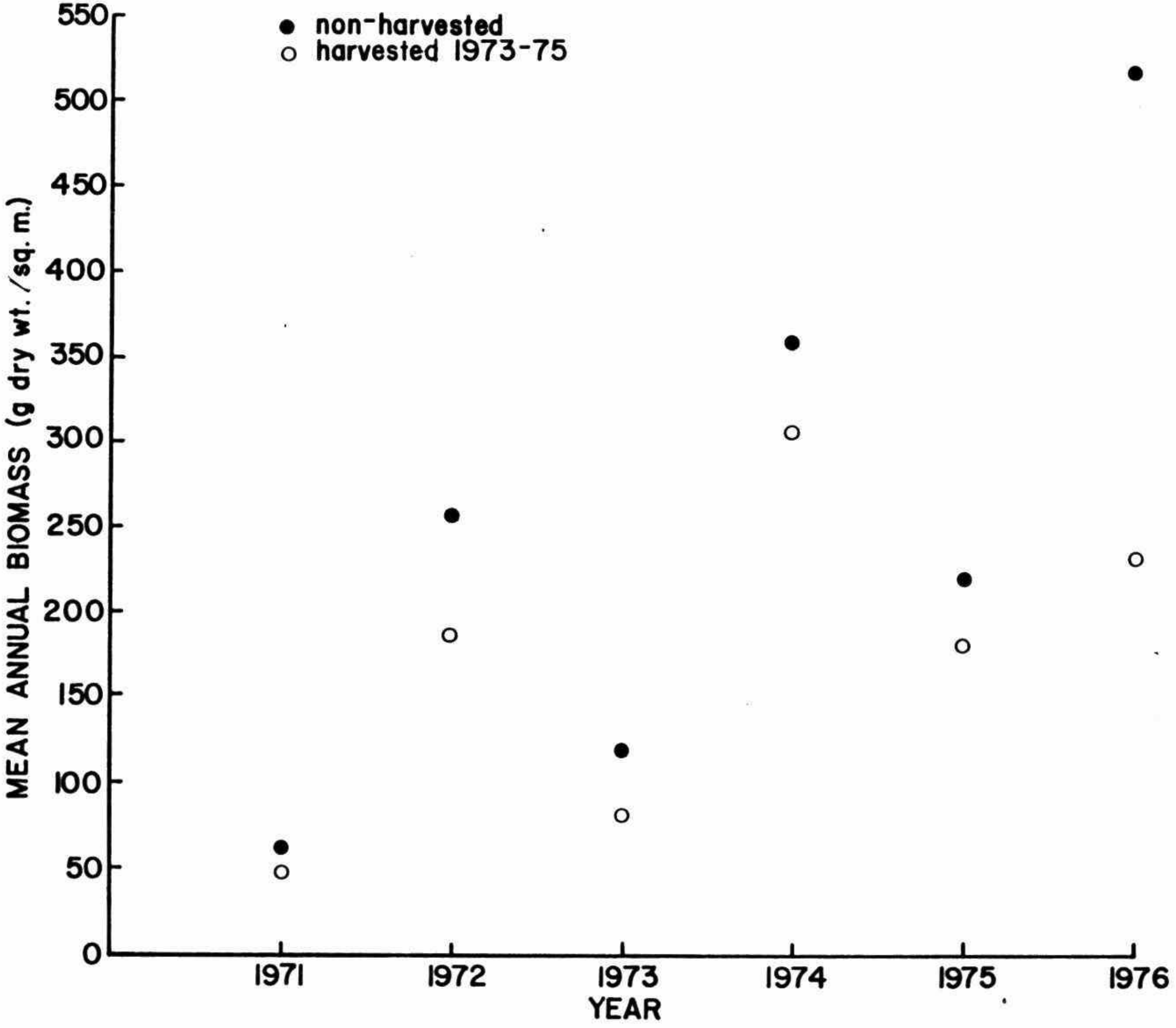

Fig. II. Mean annual plant biomass at a harvested and adjacent non-harvested site in Southern Chemung Lake.

CHAPTER 8

THE FISHERIES OF CHEMUNG LAKE

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INTRODUCTION

Aquatic plants form an important component of the fish and wildlife habitat in a lake by providing shelter and feeding areas for many species. Gaevskaya (1966) reported at least 603 species of aquatic animals feed on hygrophytes. Some fish species such as yellow perch and maskinonge spawn in shallow vegetated areas of lakes and streams. Eggs of the former species are attached to the vegetation while those of the latter merely settle into the protection of the foliage (Scott and Crossman, 1973).

The purpose of this study was to investigate the relationships between aquatic plant abundance and the fisheries of Chemung Lake. In addition an effort was made to determine the potential impact of chemical and harvest control of aquatics on the fisheries.

METHODS

A causeway at Bridgenorth divides Chemung Lake into two sectors, one of 800 ha in the south and one of 1480 ha in the north (Fig. 1). This causeway served as a readily identifiable boundary between the treatment and control areas. Aquatic plant harvesting operations were confined to the southern sector during the study, beginning in August of 1973 but commencing in June of 1974 and 1975 and terminating at the end of October in each year. Preharvest data were obtained during 1971 through 1973 and the effects of the on-going harvesting were monitored in 1974 and 1975.

Four methods of investigation were utilized: 1) trapnetting for large fish (<20 cm); 2) rotenone poisoning (in quadrats) for small fish; 3) sampling of harvested plant material for entrapped fish; and 4) creel census for angling pressure, species landed and catch-effort statistics.

Trapnetting

Four (1.2 m), six (1.8 m) and eight (2.4 m) foot trapnets were used to sample the fish in Chemung Lake. A total of 24 locations in the southern area and eight locations in the northern area were sampled during the five years of the study (Fig. 1). Not all locations were used each year, however, location III in the south, and location VI in the north were sampled each year. The netting schedule is shown in Appendix IA.

Netted fish were counted, identified by species and recorded by net to allow comparisons net to net and year to year (Appendix IB and C). Fish captured in the south were either fin-clipped or tagged (depending on species) and released. Recaptures of marked fish were used to determine population estimates (Appendix ID). Trapnets in the north served as a check on migration from the south.

Rotenone Quadrats

Twelve areas were selected for sampling small fish with rotenone (Fig. 1). Each quadrat (100 m^2) was enclosed with netting covered on the inside with heavy gauge plastic and weighted on the bottom with leads and a heavy steel chain to ensure against escapement. Gear limitations set the maximum depth of any quadrat at 1.5 m. The netting was then raised for an overnight accommodation period, then closed and rotenone added to achieve a uniform concentration of two parts per million. One hundred percent collection of fish was attempted using both surface collection and diving.

Fish samples were preserved in preweighed plastic bags of 5% formalin and ionol colour preservative solution. Larger, readily identifiable fish were recorded by species, weighed, measured for total length and then discarded. Preserved fish were mass-weighed and individually measured upon completion of sampling. Fish over 20 cm in total length were omitted from the final statistical analysis to avoid undue bias associated with the infrequency of their capture in the shallow quadrats. Samples of fish were identified at the Royal Ontario Museum for the 1972 and 1973 samples. Subsequent years' collections were identified at the Biology Department of Trent University.

Vegetation density within each quadrat was estimated visually based on the percentage of bottom covered by plants added to a factor for mean plant height expressed as a percentage of the mean water depth. These were called "growth indices" and were expressed on a scale of 0 to 200 for comparisons with fish data from each quadrat (Appendix II A-E).

Harvested Plant Samples

Throughout the 1974 and 1975 harvest operations samples of plant material were taken randomly from the transport barges, weighed wet and sorted for fish tangled in the foliage. These fish were all identified and measured for total length. Weights were estimated by comparing these fish to weights obtained for fish of similar size and species taken from the rotenone plots (Appendix III A-B).

Creel Census

Stratified creel census data were collected throughout the summers of 1971 to 1976 inclusive, with more or less equal emphasis on both the north and south areas of the lake. Census techniques and analyses were modified from those described by J.J. Armstrong (1967). The angling day was standardized at 0600 to 2200 hours with no estimates added for fishing outside this time span. A rotational method of date and time selection was used to determine sampling periods thus giving equal emphasis to each day of the week, and morning, afternoon and evening time periods.

Subsequent to an initial observation period to establish areas of boat concentration, random boat counts were made to determine total effort. Anglers were contacted in order of priority based on concentration with all areas of the lake receiving some sampling. Anglers were asked about the following 1) hours fished; 2) species sought; and 3) species kept. Fish kept were recorded and total lengths measured. Weights were estimated using length-weight regressions determined from trapnet sampling. Creel data are summarized in Appendix IV A-D.

RESULTS

Trapnetting

Numerically, pumpkinseed dominated trapnet returns followed by either yellow perch or walleye (Table 1). The perch catches declined significantly during 1974 and 1975 in both the northern and southern sectors. Population estimates (Table 2) demonstrated close agreement with trapnet order of dominance with only minor changes in numerical hierarchy. Again only yellow perch demonstrated any significant changes in population level considering sample sizes for the individual species studied.

TABLE 1. Relative abundance of fish species in Chemung Lake (1972-1975) based on summer trap-net catches in the northern and southern sectors. Numbers in parentheses are catch/100 net-days.

SOUTHERN SECTOR

Rank	1972	1973	1974	1975
1	Pumpkinseed (2160)	Pumpkinseed (1370)	Pumpkinseed (2720)	Pumpkinseed (2510)
2	Perch (523)	Y. Perch (1160)	Walleye (837)	Walleye (756)
3	Walleye (329)	Walleye (646)	Bullhead (401)	Rock Bass (415)
4	Rock Bass (322)	Bullhead (234)	Rock Bass (381)	Bullhead (331)
5	Bullhead (303)	Rock Bass (205)	W. Sucker (205)	W. Sucker (129)
6	W. Sucker (144)	W. Sucker (116)	Y. Perch (162)	S.M. Bass (106)
7	L.M. Bass (47.9)	S.M. Bass (43.3)	S.M. Bass (86.6)	Y. Perch (75.6)
8	S.M. Bass (44.1)	Carp (32.2)	L.M. Bass (39.5)	Carp (55.2)
9	Carp (16.2)	Maskinonge (16.7)	Carp (38.5)	L.M. Bass (39.4)
10	Maskinonge (14.0)	L.M. Bass (14.1)	Maskinonge (9.9)	Maskinonge (12.9)

NORTHERN SECTOR

1	Pumpkinseed (6960)	Pumpkinseed (4210)	Pumpkinseed (1630)	Pumpkinseed (2000)
2	Walleye (1810)	Walleye (1200)	Walleye (476)	Walleye (954)
3	Y. Perch (384)	Y. Perch (779)	W. Sucker (214)	W. Sucker (214)
4	S.M. Bass (327)	W. Sucker (301)	Y. Perch (167)	S.M. Bass (120)
5	W. Sucker (323)	Bullhead (122)	S.M. Bass (93.7)	Carp (107)
6	Rock Bass (188)	Rock Bass (107)	Bullhead (49.1)	L.M. Bass (83.0)
7	Bullhead (176)	S.M. Bass (103)	Rock Bass (42.8)	Y. Perch (67.8)
8	Carp (161)	L.M. Bass (75.8)	L.M. Bass (24.2)	Bullhead (38.1)
9	L.M. Bass (128)	Carp (21.5)	Carp (19.2)	Rock Bass (30.1)
10	Maskinonge (12.9)	Maskinonge (7.00)	Maskinonge (0.600)	Maskinonge (8.00)

TABLE 2. Relative population densities (fish/HA) from population estimates for southern Chemung Lake 1971-1975, based on mark/recapture data (tag and/or clip).

	1971			1972			1973			1974			1975		
	Species	Density		Species	Density		Species	Density		Species	Density		Species	Density	
Rank		Tag	Clip		Tag	Clip		Tag	Clip		Tag	Clip		Tag	Clip
1	Walleye	37.2	43.6	Pumpkinseed		108	Pumpkinseed		124	Pumpkinseed		91.9	Pumpkinseed		173
2	Maskinonge	1.90		Y. Perch		45.7	Y. Perch		124	Walleye		36.6	Walleye	35.1	40.8
3	L.M. Bass	1.28	1.48	Walleye		21.5	Walleye		48.3	W. Sucker		16.5	Rockbass		19.5
4	S.M. Bass	0.60	0.90	W. Sucker		12.5	Bullhead		13.6	Rockbass		16.2	W. Sucker		15.4
5				Rock Bass		12.4	W. Sucker		9.10	Carp	13.6		Bullhead		7.79
6				Bullhead		11.5	Rockbass		8.61	Bullhead		9.53	Carp	5.18	
7				Carp		0.87	Carp	8.03		Y. Perch		4.98	Y. Perch	4.48	3.12
8				Maskinonge	0.86		S.M. Bass	5.78	1.03	S.M. Bass	3.51	1.55	S.M. Bass	2.23	2.25
9				S.M. Bass	0.97	0.42	Maskinonge	0.69		Maskinonge	0.87		L.M. Bass	1.25	1.68
10				L.M. Bass	0.30	0.18	L.M. Bass	0.69	0.27	L.M. Bass	1.16	0.56	Maskinonge		

Rotenone Quadrats

Annual fish returns from individual quadrats failed to show any obvious relationships with the plant growth index. However, when the values of plant density for each quadrat were averaged over the 4 years and compared with mean returns of fish, statistically significant relationships between both fish numbers and weights were observed. Regression analysis of mean fish numbers against mean plant density yielded the following relationship:

$y = 2.23X - 35.7$ ($r = 0.94$)

where y = number of fish with length less than 20 cm per 100 m^2

x = mean plant growth index

(Fig. 2)

Regression of fish weights against mean plant growth index yielded the following relationship:

$y = 4.72X + 156$ ($r = 0.70$)

where y = weight in gm of fish with length less than 20 cm per 100 m^2

x = mean plant growth index

(Fig. 3)

Twenty-one species of fish were collected from the quadrats over four years (Table 3). Yellow perch were dominant in the collections in all years but declined by about 50% between 1973 and 1974.

Harvested Plant Samples

Two hundred and two samples of harvested plant material were taken over the 1974 and 1975 harvest seasons. The wet-weight ratio of plants to fish trapped in the foliage was found to be approximately 1000:1 (Table 4). small yellow perch were most numerous, accounting for 56 percent of the total sample. Fish in the sample were small having a mean length of 54 mm with a range of 12 to 190 mm.

Creel Census

Creel data were collected from 11,284 anglers over the years 1971 to 1976 inclusive. Angler effort and catch statistics were predominantly

TABLE 3. Fish species and catch rates from rotenone quadrats (100 m^2) in peripheral areas of the southern sector of Chemung Lake

Species	1972	1973	1974	1975	Mean Catch Rate
		number/quadrat			
Yellow perch	150	158	78.8	79.9	123
Pumpkinseed	26.0	28.5	49.7	63.5	40.6
Rockbass	44.1	36.4	31.2	25.7	34.8
Bullhead	2.5	9.6	0.3	47.5	16.7
Spottail shiner	9.4	3.2	2.7	18.5	9.0
Iowa darter	1.3	5.3	11.7	14.9	7.8
Smallmouth bass	3.1	18.1	0.3	0.3	6.4
Golden shiner	10.4	8.7	5.0	0.3	6.3
Largemouth bass	2.7	6.8	7.7	5.6	5.5
Bluntnose minnow	0.7	2.4	3.3	12.7	4.9
Carp	3.2	1.6	0.5	0.5	1.6
Fantail darter	3.6	0.0	0.0	0.0	1.0
Brook stickleback	0.6	0.4	0.0	0.0	0.3
White sucker	0.0	0.6	0.3	0.3	0.3
Blackchin shiner	0.0	0.8	0.0	0.0	0.2
Walleye	0.0	0.2	0.3	0.1	0.1
Banded killifish	0.0	0.0	0.0	0.3	0.08
Mottled sculpin	0.1	0.1	0.2	0.0	0.08
Central mudminnow	0.2	0.0	0.0	0.0	0.04
Blacknosed shiner	0.0	0.0	0.2	0.0	0.02
Slimy sculpin	0.0	0.0	0.2	0.0	0.02

TABLE 4. Fish samples collected from harvested aquatic plants from southern Chemung Lake in 1974 and 1975

Year	No. of plant samples	Mean plant wet weight/sample (kg)	Mean no. fish/sample	Mean weight fish/sample (g)	Wet weight ratio plants:fish	Mean no. of fish per kg of plants
1974	74	10.5	2.39	10.24	1000 : 0.98	0.23
1975	128	10.4	3.72	11.01	1000 : 1.06	0.36
Total	202	10.4	3.23	10.73	1000 : 1.03	0.31

higher for the southern sector than the northern sector (Table 5, Fig. 4-6). Creel data indicated a peak in angler effort in 1972 for both the northern and southern sectors followed by a continuous decline through 1976. Over ninety percent of the anglers contacted each year were primarily interested in fishing walleye even though walleye returns to the angler declined in the northern sector. In the south, walleye returns remained fairly constant while total fish returns to the angler declined in both areas especially from 1974. A common measure of angler success, catch per unit of effort (Fig. 6), exhibited considerable variability but even so indicated downward trends especially for the northern sector.

DISCUSSION

Systems analysis is, of necessity, based on the observation of variables (Kerr, 1976). Further, success in problem solving is dependent on matching the order of complexity of the solution to the complexity of the problem (Regier _et al_, 1974). One problem then has been in selecting variables for observation which would demonstrate the interrelationship between aquatic plant growth and fish within a system which is highly productive and complex with regard to both its flora and fauna. The second problem was to find sets of variables which would relate to the possible effects of the two methods of aquatic plant control. With each a modicum of success has been achieved.

Data from the Ontario Ministry of the Environment (Appendix IIIB) indicate stable aquatic plant production around 20 x 10^3 kg/ha over the study period in southern Chemung Lake. Indices and estimates of fish populations also suggested a certain stability with few consistent trends by species (Table 6). Yellow perch data demonstrated the only consistent decline over the various types of estimates. The decline in perch appeared to be abrupt with the drop occurring between the 1973 and 1974 seasons for both larger (trapnet) and smaller (rotenone) specimens.

The decline in perch population may be indicative of a stress response although high levels of natural variation contribute a great deal of uncertainty to any such conclusion (Christie, 1974). While perch contributed significantly to fish samples taken from harvested plants (Appendix IIIA), declining catches north of the causeway by both trapnets

TABLE 5. Angler effort and catch statistics for Chemung Lake during the years 1971-1976 (based on stratified Creel census).

Year	Angler hr /ha/100 days	% Anglers Fishing Walleye	Walleye Harvest number/ha/100 days	Fish Harvest number/ha/100 days
SOUTHERN SECTOR (800 ha.)				
1971	33.2	96.0	4.43	7.09
1972	35.7	96.1	4.13	7.14
1973	27.8	92.8	4.18	9.15
1974	29.4	93.8	5.44	9.02
1975	26.0	96.8	3.50	4.28
1976	16.4	99.6	4.34	4.49
NORTHERN SECTOR (1480 ha.)				
1971	17.3	100	2.59	4.81
1972	25.9	93.2	2.74	7.06
1973	22.9	90.1	1.96	3.86
1974	21.4	92.6	1.71	5.07
1975	17.4	91.4	0.97	1.90
1976	10.5	90.1	0.63	0.78

TABLE 6. Fish indices and estimates for Chemung Lake, southern sector, 1971-1976.

Species	Sampling Result		Year					
			1971	1972	1973	1974	1975	1976
Walleye	Trapnet Loc. III (No/100 days)		365	70.0	32.9	23.6	41.2	-
	Mean Trapnet Rate (No/100 days)		1670	329	646	837	756	-
	Population Estimate (No/HA.)	Clip	43.6	21.5	48.3	36.6	40.8	-
		Tag	37.2	-	-	-	35.1	-
	Rotenone Plots Est. (No/100m^2)		-	0.0	0.2	0.3	0.1	-
	Creel - Harvest Est. (No/HA/100 Days)		4.43	4.13	4.18	5.44	3.50	4.34
Maskinonge	Trapnet Loc. III		10.0	11.7	4.1	1.8	7.0	-
	Mean Trapnet Rate		21.4	14.0	16.7	9.9	12.9	-
	Population Estimate	Tag	1.9	0.86	0.69	0.87	-	-
	Rotenone Plots Est.		-	-	-	-	-	-
	Creel		0.06	0.08	0.05	0.02	0.08	-
Largemouth Bass	Trapnet Loc. III		215	105	27.4	32.7	85.9	-
	Mean Trapnet Rate		134	47.9	14.1	39.5	39.4	-
	Population Estimate	Clip	1.48	0.18	0.27	0.56	1.68	-
		Tag	1.28	0.30	0.69	1.16	1.25	-
	Rotenone Plots Est.		-	2.7	6.8	7.7	5.6	-
	Creel - Harvest Est.		0.06	-	0.10	0.05	0.03	-
Smallmouth Bass	Trapnet Loc. III		75.0	26.7	8.2	5.4	14.1	-
	Mean Trapnet Rate		75.7	44.1	43.3	86.6	105.7	-
	Population Estimate	Clip	0.90	0.42	1.03	1.55	2.25	-
		Tag	0.60	0.97	5.78	3.51	2.23	-
	Rotenone Plots Est.		-	3.1	18.1	0.03	0.03	-
	Creel - Harvest Est.		0.08	0.12	0.33	0.17	0.34	-
White Sucker	Trapnet Loc. III		-	86.7	60.3	52.7	78.8	-
	Mean Trapnet Rate		-	144	115.5	205.0	128.9	-
	Population Estimate	Clip	-	12.5	9.10	16.5	15.4	-
	Rotenone Plots Est.		-	0.0	0.6	0.3	0.3	-
	Creel - Harvest Est.		-	-	-	-	-	-

TABLE 6 (continued)

Species	Sampling Result		Year					
			1971	1972	1973	1974	1975	1976
Yellow Perch	Trapnet Loc. III		-	155	72.6	65.4	17.6	-
	Mean Trapnet Rate		-	523	1164	161.5	75.6	-
	Population Estimate	Clip	-	45.7	124	4.98	3.12	-
		Tag	-	-	-	-	4.48	-
	Rotenone Plots Est.		-	150	158	78.8	79.9	-
	Creel - Harvest Est.		2.18	2.22	3.23	1.60	0.17	0.10
Pumpkinseed	Trapnet Loc. III (No/100 days)		-	6210	1672	4165	2276	-
	Mean Trapnet Rate (No/100 days)		-	2160	1372	2724	2509	-
	Population Estimate (No./HA.)	Clip	-	108	124	91.9	173	-
	Rotenone Plots Est. (No/100m^2)		-	26.0	28.5	49.7	63.5	-
	Creel - Harvest Est (No/ha/100/ days		0.13	4.42	0.86	0.73	-	-
Rockbass	Trapnet Loc. III		-	1260	301.4	430.9	235.3	-
	Mean Trapnet Rate		-	322	204.9	381.3	414.8	-
	Population Estimate	Clip	-	12.4	8.61	16.2	19.5	-
	Rotenone Plots Est.		-	44.1	36.4	31.2	25.7	-
	Creel - Harvest Est.		0.08	0.08	0.31	0.46	0.13	-
Bullhead	Trapnet Loc. III		-	720	458	145	259	-
	Mean Trapnet Rate		-	303	232	401	331	-
	Population Estimate	Clip	-	11.5	13.6	9.53	7.79	-
	Rotenone Plots Est.		-	2.5	9.6	0.3	47.5	-
	Creel - Harvest Est.		0.05	0.07	0.09	0.55	0.04	-
Carp	Trapnet Loc. III		-	13.3	37.0	7.3	7.0	-
	Mean Trapnet Rate		-	16.2	32.2	38.5	55.2	-
	Population Estimate	Clip	-	0.87	-	-	-	-
		Tag	-	-	8.03	13.6	5.18	-
	Rotenone Plots Est.		-	3.2	1.6	0.5	0.5	-
	Creel - Harvest Est.		-	-	-	-	-	-

and anglers would seemingly exonerate harvester activity as a cause.

In spite of stable fish populations angler effort on the lake declined by over 50 percent of peak values for both areas of the lake (Table 5). This is all the more surprising for the southern area since over 90 percent of anglers were primarily interested in walleye and the walleye harvest remained relatively constant from 1971 through 1976. From the data on hand it is difficult to perceive a cause and effect relationship unless the decline of angler effort is related more to total fish harvest (Table 5) rather than to the species of primary interest. If such were the case, angler effort should mirror but lag the decline in fish harvest. This does not appear to be the case especially in southern Chemung where declining fish harvest lagged the declining effort.

Another possible cause of declining fishing effort is a proliferation of aquatic plants. Their interference with small boat traffic and fishing by fouling propellers and lures may be truly frustrating to the anglers thus reducing effort regardless of catch. Also during the period of the study the Kawartha Lakes in general and Chemung Lake in particular received a certain notoriety through press releases concerning nuisance growths of aquatic vegetation. This notoriety may also have served to reduce angling pressure.

In marginal areas of the southern sector of Chemung Lake definite relationships of fish numbers and weights with plant density were established. These relationships were used to develop an hypothetical effect on fishes of chemical control of aquatic plants. The following three assumptions were used in the synthesis:

1. Cottagers are likely to treat areas of plant growths close to shore where relationships found between fish and plants apply most specifically.

2. Areas selected for treatment will have submergent plant densities in the range of medium to heavy (plant growth index = 150 on average).

3. Chemical treatment will result in at least partial control reducing plant density to a level between zero and light (plant growth index = 0 to 50).

From this information it was found that chemical control of aquatic plants would reduce the carrying capacity for small fish in the order of 75 to 100 percent by number or 55 to 82 percent by weight. Displacement of fish would therefore be in the range of 22 x 10^3 to 30 x 10^3 fish or 47 to 71 kg of fish per hectare treated. If it is considered axiomatic that in natural environments, populations are always crowding the upper limit of their carrying capacities then it is likely that these displaced individuals are lost to the system. One of the more likely avenues would be through increased predation because of loss of cover. The loss might also be expressed not as a loss of individuals per se, but rather through a general change in the "condition" of individuals through increased competition for nutrient in the remaining cover. Whatever the final resolution of the reduced carrying capacity it can be expected that the effect on these small fish will be reflected through the food web and impinge upon the status of the top predators. Table 7.

Harvesting of plants accounted for a direct loss of fish as opposed to the indirect loss hypothesized for chemical control. This loss was in the range of 8.9 kg or 2.8 x 10^3 fish for each ha treated (Table 8). On an areal basis, harvesting may have less impact on the fishery than chemical control. This reduced impact is attributable in large measure to the reduced efficiency in clearing the vegetation from an area. It should be stressed that quite apart from the direct loss of fish, some loss may accrue through the removal of cover as postulated for chemical control. Examination of six samples of floating vegetation suggested that direct loss of fish could be reduced by cutting the plants and allowing them to float before harvesting (Appendix IIIB). Lack of efficiency in cleaning up an area and additional costs for containment of floating vegetation could, however, present major obstacles for this technique.

Another interesting, if accidental, aspect of the aquatic plant harvesting data is the agreement between the estimate of direct loss of fish with the estimated annual allowable harvest (8.9 kg/ha) for Chemung Lake using Ryder's morphoedaphic index (Lewies, 1976). Since the index was derived empirically using commercial catch data for the most part, calculations of the allowable harvest ignored fish of the size taken by the harvester (mean weight in the range of 2-3 gm). These smaller fish are from a lower stratum of the pyramid of numbers typical of biological populations

TABLE 7. The hypothetical effect on fishes of chemical control of aquatic plants, based on rotenone quadrat data from peripheral areas of the southern sector of Chemung Lake.

Plant Cover	Assumed Plant Growth Index	Fish Density Number/ha	Fish Weight kg/ha	Estimated % Loss of Fish/ha Number	Weight
Pre-treatment Medium to Heavy	150	29,880	86.4		
Post-treatment zero to light	0 to 50	0 to 7580	15.6 to 39.2		
Displacement of Fish		22,300 to 29,880	47.2 to 70.8	75 to 100	55 to 82

TABLE 8. The effect on fishes of harvest control of aquatic plants, based on fish recovered from random samples of harvested material in a ratio of 1:1000 by wet weight, and a rate of .31 fish per kg of harvested plant material.

	Plant Harvest			Estimated Fish Harvest			
Year	Area (ha)	Wet Weight (kg)	(kg/ha)	Wet Weight (kg)	(kg/ha)	Number	Number/ha
1974	262	1.93x10^{6}					
1975	297	3.02x10^{6}					
Total	559	4.95x10^{6}	8.86x10^{3}	4.95x10^{3}	8.86	1.53x10^{6}	2.75x10^{3}

and likely their harvest should be considered as separate and distinct from that determined by the morphoedaphic index (Fig. 7). Because the system is in some state of "dynamic·equilibrium" there should be a mutual impact of fish harvest from one stratum upon another but it is doubtful if a kg of fish from a lower stratum is equivalent to or as significant as a kg of fish from a higher level.

Plant harvesting has an additional advantage over chemical control of plants in an enriched system by removing nutrients from the internal cycle. This is particularly advantageous where there is concern for water quality and nutrient removal can be made equal to or greater than input. In addition harvest operations as practiced in this investigation encompassed 200 to 300 ha per year while chemical control has been in the range of only 50 ha per year for the whole of Chemung Lake. At these rates the direct loss of fish to the harvester is more equivalent to the displacement of fish by the chemical control. Should chemical control be required over large areas, massive fish displacement could seriously alter the present equilibrium state of the fish populations. Excessive treatments with chemicals could also place a great demand on dissolved oxygen within that area of the lake through aerobic decomposition of the vegetation. Subdividing the area into small units and spacing treatments of the units over time would alleviate this hazard.

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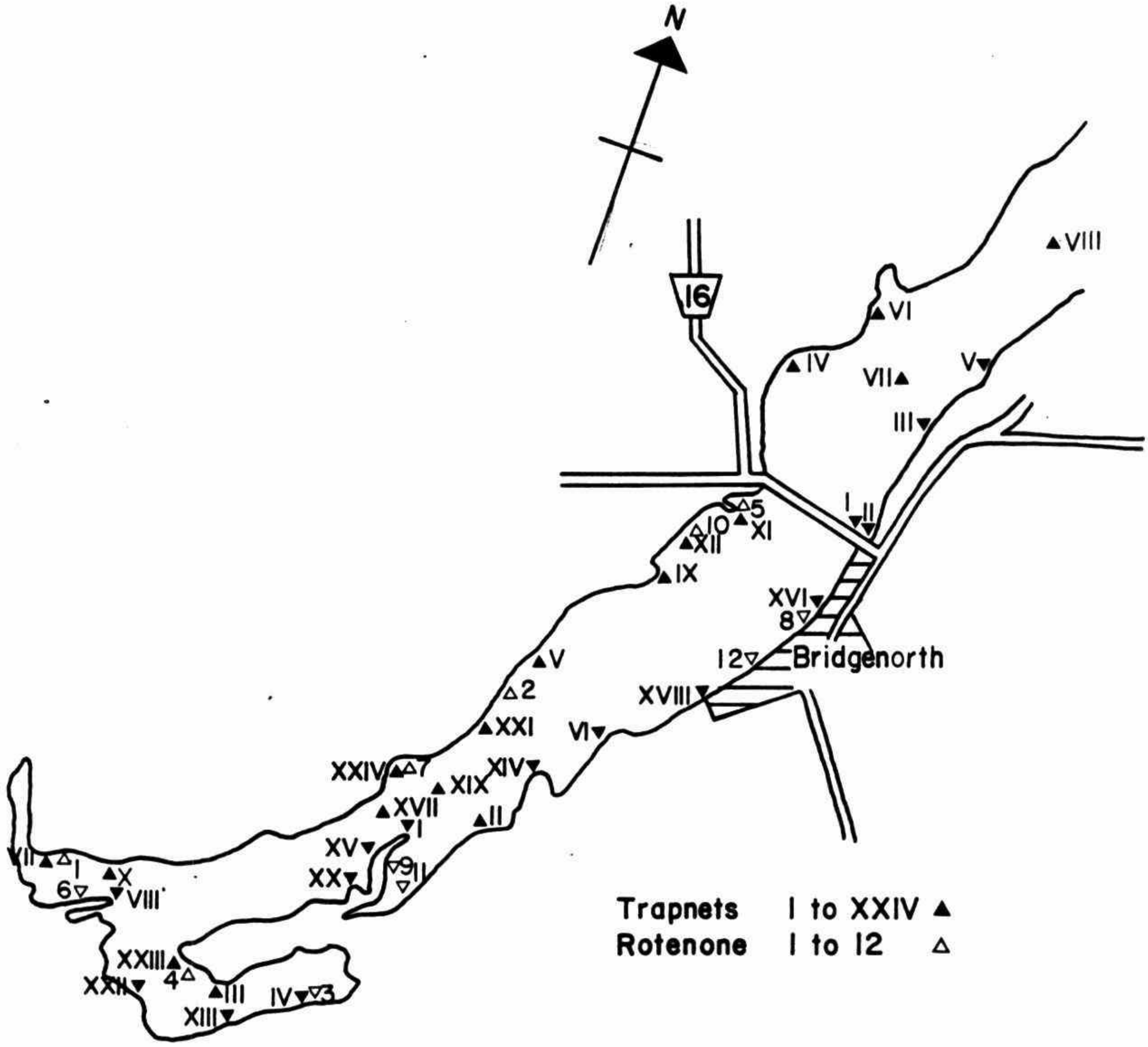

Figure I. Trapnet and Rotenone quadrat locations in Chemung Lake.

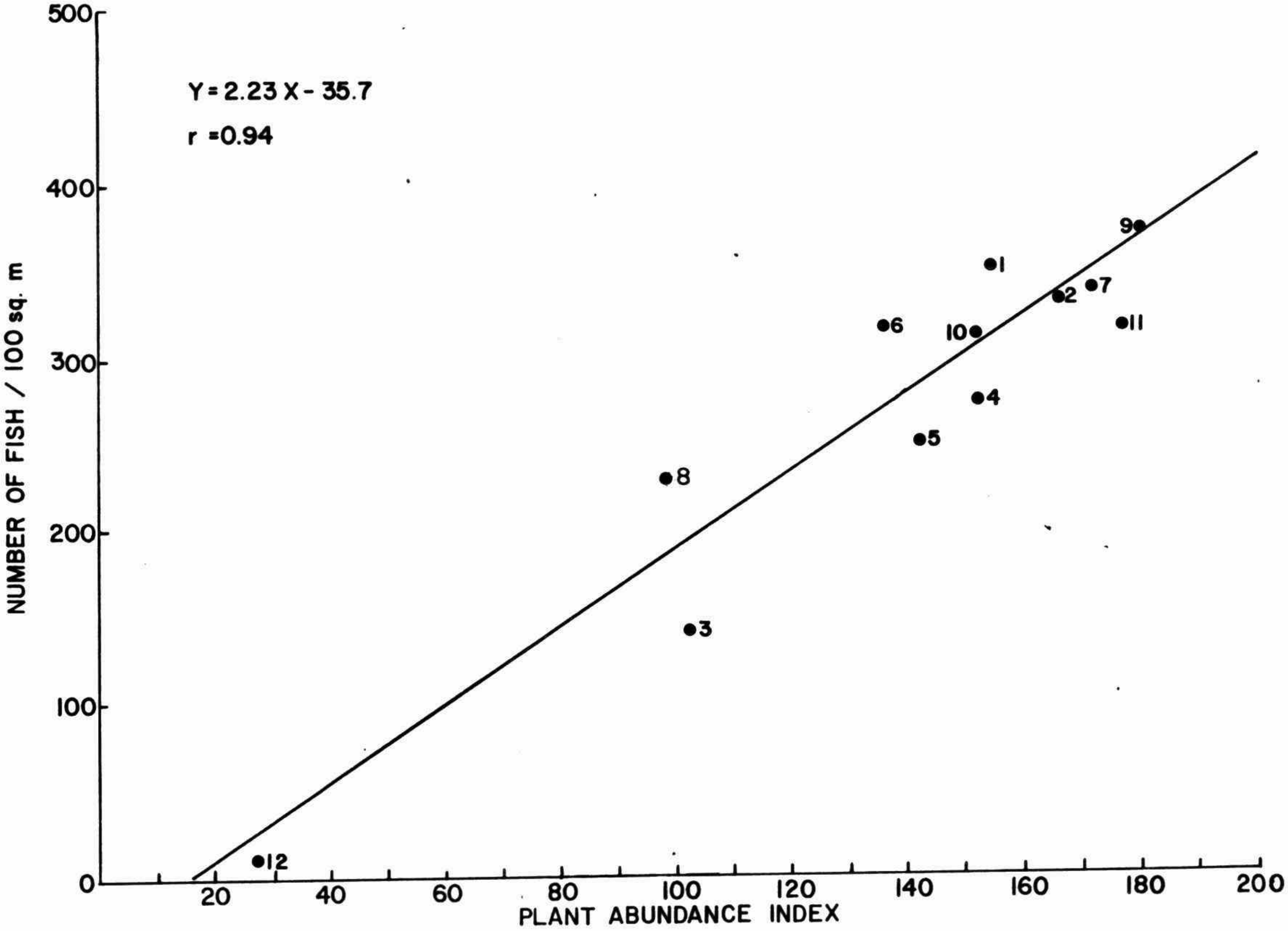

Figure 2. Relationship between submergent aquatic plant density and numbers of fish of total length less than 20 cm (southern Chemung Lake).

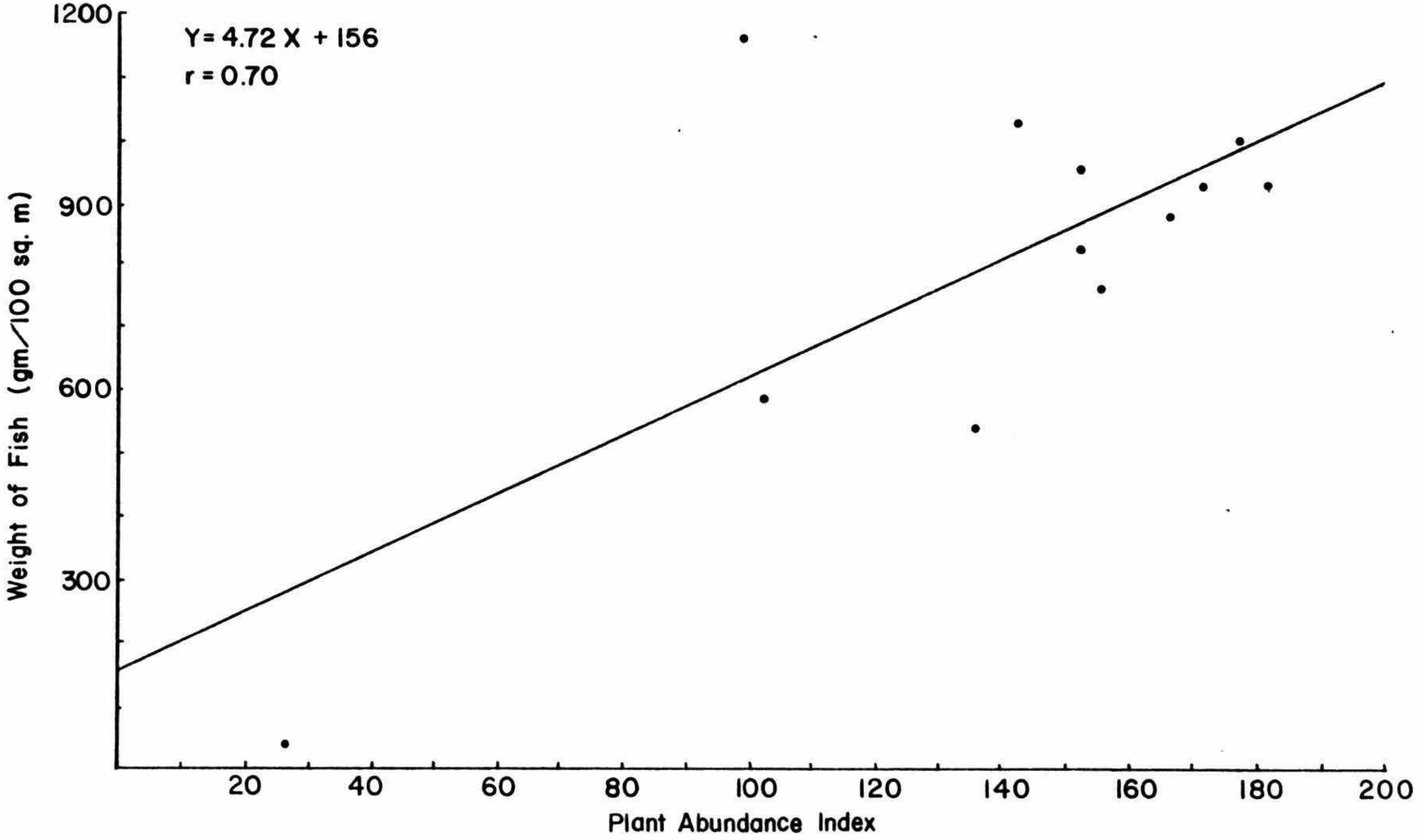

Figure 3. Relationship between submergent aquatic plant density and weight of fish (southern Chemung Lake).

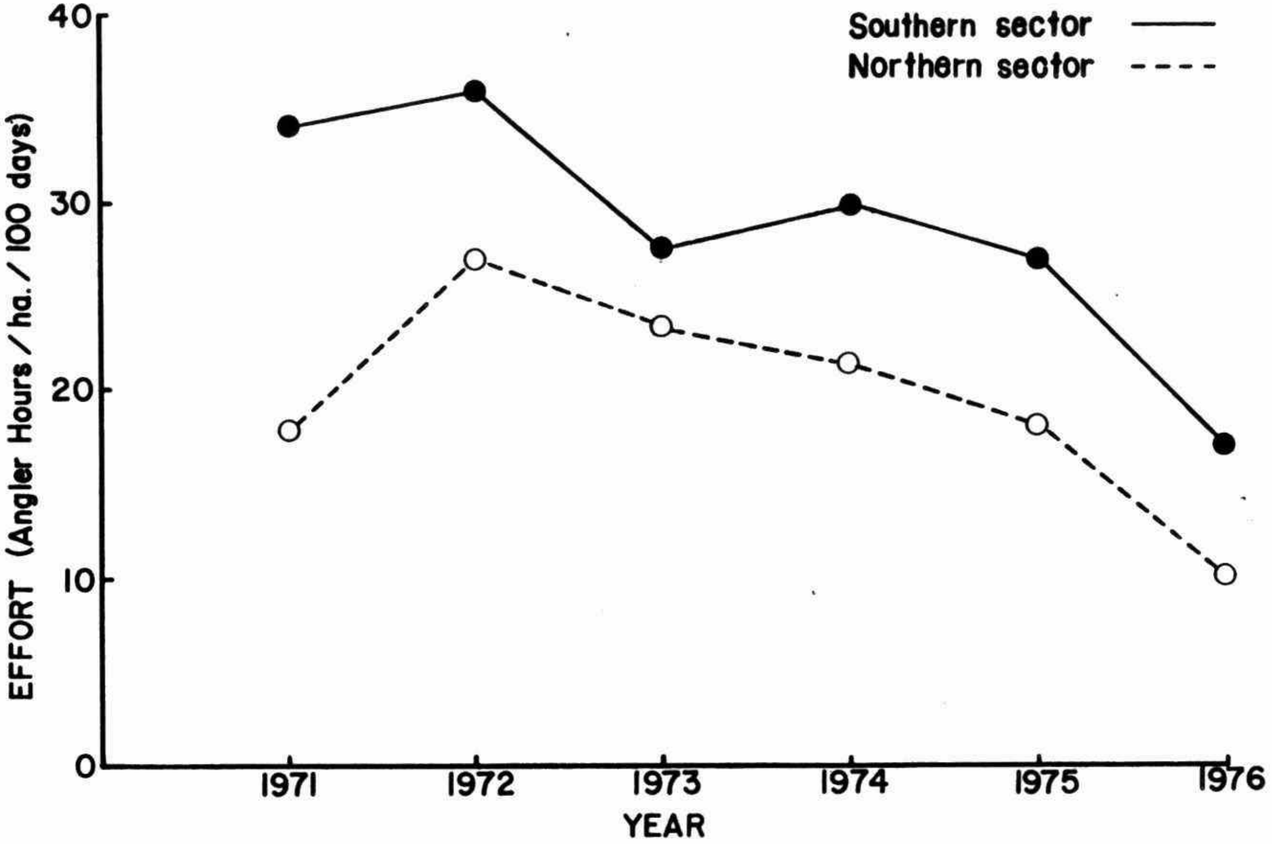

Figure 4. Trends in angler effort for Chemung Lake.

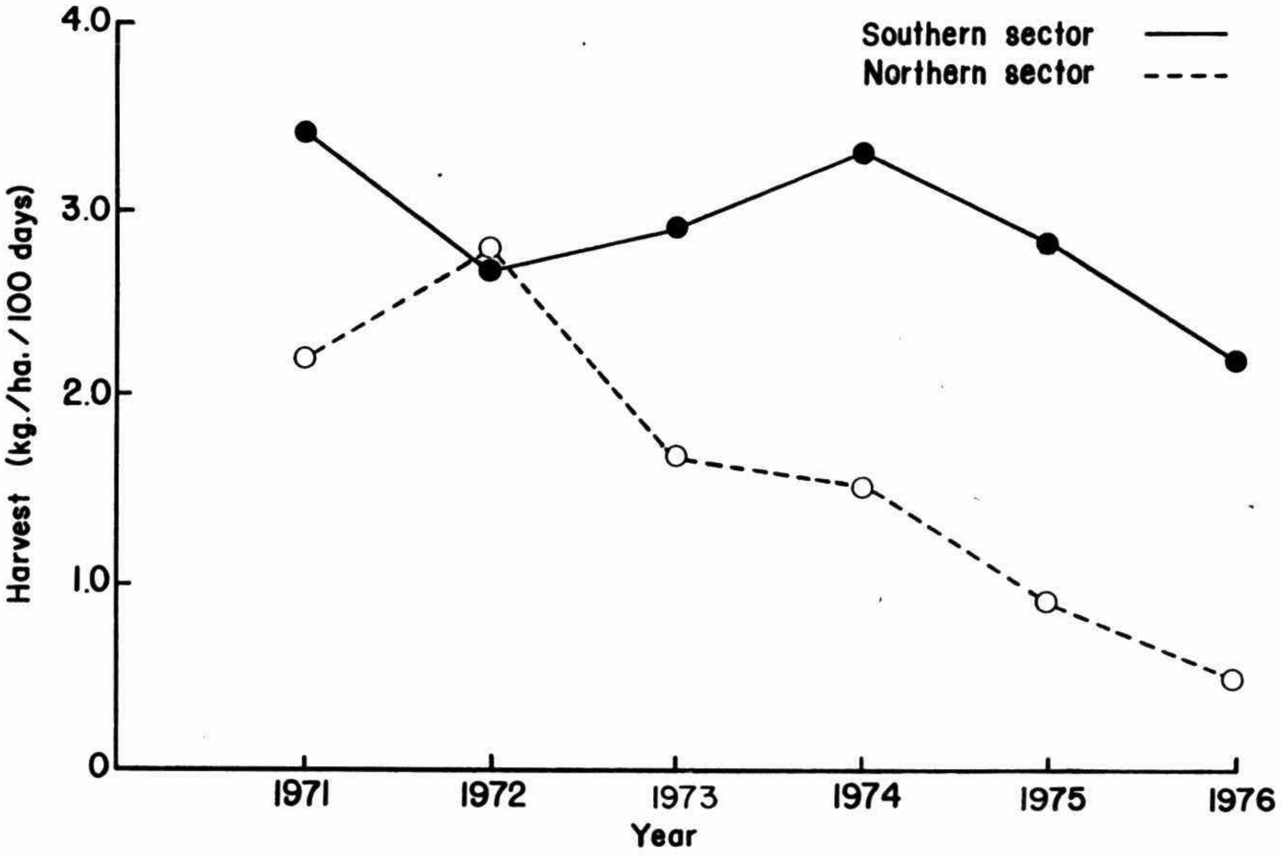

Figure 5. Trends in total estimated fish harvest for Chemung Lake.

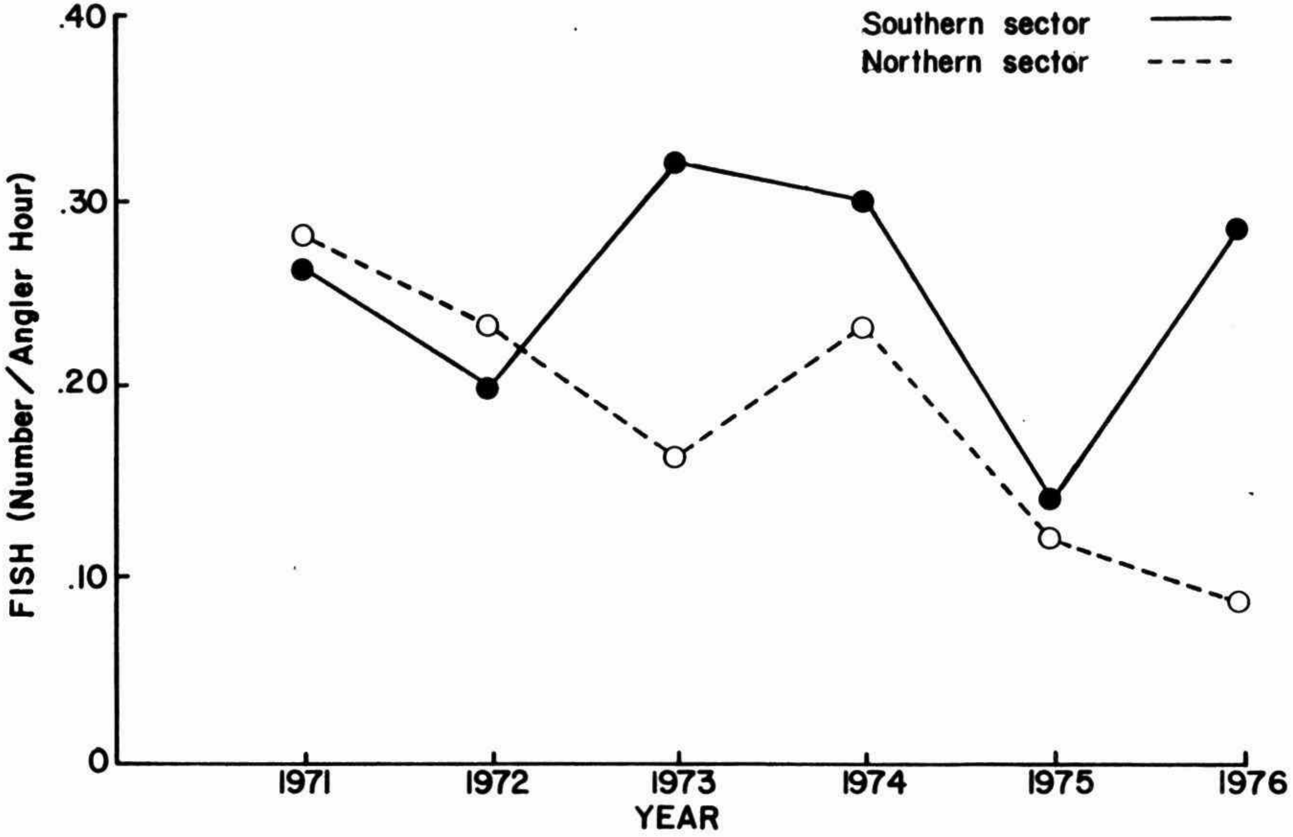

Figure 6. Trends in angler catch per unit of effort in Chemung Lake.

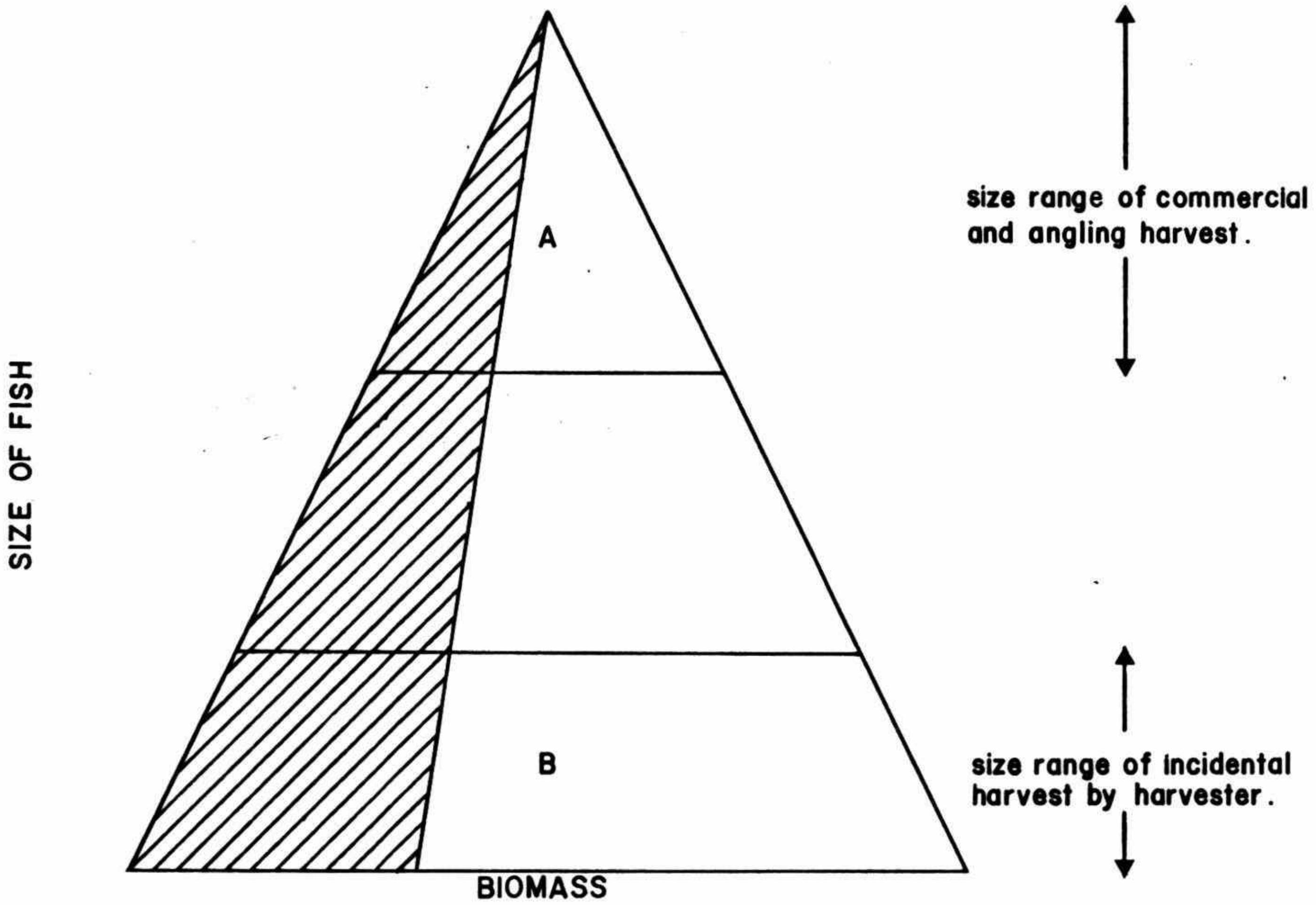
size range of commercial and angling harvest.
A
SIZE OF FISH
B
size range of incidental harvest by harvester.
BIOMASS

Figure 7. Schematic diagram of the relationship between fish biomass and size of fish, showing postulated allowable harvest (▨), segment of population used for Ryder's Morphoedaphic Index estimate of allowable harvest (A), and size of fish taken by aquatic plant harvester (B).

APPENDIX

APPENDIX 1A: CHEMUNG LAKE TRAPNETTING. Dates and designated areas fished by trap-net on Chemung Lake, 1971-1976 (location-numbers correspond to those in Fig. 1).

SOUTHERN SECTOR

YEAR	Netting Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
1971	May 19-July 15	X	X	X	X	X	X	X	X	X	X	X													
1972	May 17-Aug. 29		X	X		X		X					X	X	X	X	X	X	X						
1973	May 23-Aug. 22			X			X	X		X		X								X	X	X			
1974	May 23-Aug. 18		X	X		X			X	X		X			X		X			X			X	X	X
1975	May 22-Aug. 19			X					X	X		X	X		X		X							X	

NORTHERN SECTOR

YEAR	Netting Period	I	II	III	IV	V	VI	VII	VIII
1971	June 23-July 15	X	X	X	X	X	X		
1972	May 24-Aug. 29			X	X	X	X	X	
1973	May 24-July 27					X	X	X	
1974	May 24-Aug. 19			X			X	X	X
1975	May 22-Aug. 17			X			X		X

APPENDIX 1B: CHEMUNG LAKE - NETTING CATCH EFFORT, 1971-1975.

Catch of Fish

YEAR	Net Days of Effort			Walleye			Maskinonge			Largemouth Bass			Smallmouth Bass		
	N	S	Total	N	S	T	N	S	T	N	S	T	N	S	T
1971	70	317	387	691	5,295	5,936	4	68	72	47	424	471	75	240	315
1972	178	365	543	3,216	1,202	4,418	21	53	74	228	175	403	582	161	743
1973	186	510	696	2,240	3,295	5,535	13	85	98	141	72	213	191	221	412
1974	334	577	911	1,591	4,828	6,419	2	57	59	81	228	309	313	500	813
1975	289	667	956	2,758	5,040	7,798	23	86	104	240	263	503	348	705	1,053
Total	1,057	2,436	3,493	10,496	19,660	30,156	65	347	412	737	1,162	1,899	1,509	1,827	3,336
Less 1971	987	2,119	3,106	9,805	14,365	24,170	61	279	340	690	738	1,428	1,434	1,587	3,021

Rate of Catch (Fish/100 net days)

YEAR				Walleye N	Walleye S	Walleye T	Maskinonge N	Maskinonge S	Maskinonge T	Largemouth Bass N	Largemouth Bass S	Largemouth Bass T	Smallmouth Bass N	Smallmouth Bass S	Smallmouth Bass T
1971				987.1	1,670	1,547	5.7	21.4	18.6	67.1	133.8	121.7	107.1	75.7	81.4
1972				1,807	329.3	813.6	12.9	14.0	13.6	123.1	47.9	74.2	327.0	44.1	136.8
1973				1,254	146.1	795.1	7.0	16.7	14.1	75.8	14.1	30.6	102.7	43.3	59.2
1974				476.3	836.7	704.6	0.6	9.9	6.5	24.2	39.5	33.9	93.7	86.6	89.2
1975				954.3	735.6	815.7	8.0	12.9	11.4	83.0	39.4	52.6	120.4	105.7	110.1
Mean Rate				993.0	807.1	863.3	6.1	14.2	11.8	69.7	47.7	54.4	142.8	75.0	95.5

APPENDIX 1B - Cont'd....

Catch of Fish

Pumpkinseed			Yellow Perch			Rock Bass			White Sucker			Bullhead			Carp		
N	S	T	N	S	T	N	S	T	N	S	T	N	S	T	N	S	T
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,383	7,866	20,249	683	1,903	2,591	334	1,174	1,508	575	525	1,100	313	1,106	1,419	287	59	346
7,824	6,998	14,826	1,449	5,736	7,185	199	1,045	1,244	560	589	1,149	227	1,182	1,409	40	164	104
5,459	15,715	21,174	559	932	1,491	143	2,200	2,343	713	1,183	1,896	164	2,314	2,478	64	222	286
5,787	16,734	22,521	196	504	700	87	2,767	2,854	620	860	1,480	110	2,208	2,318	310	368	678
31,457	47,313	78,770	2,887	9,080	11,967	763	7,186	7,949	2,468	3,157	5,625	814	6,810	7,624	701	813	1,516
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rate of Catch (Fish/100 net days)																	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6,957	2,160	3,729	383.7	523	477.2	137.6	322	277.7	323	144	202.6	175.8	303	261.3	161.2	16.2	63.2
4,208	1,372	2,130	779.0	1,164	1,032	107.0	204.9	178.7	301.1	155.5	165.1	120.0	231.8	202.4	21.5	32.2	29
1,634	2,724	2,324	167.4	161.5	163.7	42.8	381.3	257.2	213.5	205.0	208.1	49.1	401.0	272.0	19.2	38.5	31
2,002	2,509	2,356	67.8	75.6	73.2	30.1	414.8	293.5	214.5	128.9	154.8	38.1	331.0	242.5	107.3	55.2	70
3,189	2,233	2,536	292.5	428.5	385.3	77.3	339.1	255.9	250.0	149.0	181.1	82.5	321.4	245.5	71.0	38.4	48

APPENDIX 1C. CHEMUNG LAKE - RATE OF CATCH EFFORT BY NET LOCATION, 1971-1975.

Catch/100 Net Days

Loc. No.	Days of Effort	Walleye	Maskinonge	L.M. Bass	S.M. Bass
SOUTHERN SECTOR 1971					
I	18	1618	82.4	0	76.5
II	31	3197	45.2	80.6	164.5
III	20	365	10.0	215.0	75.0
IV	21	438	38.1	300.0	33.3
V	49	378	8.2	61.2	24.5
VI	47	1798	2.1	4.2	27.7
VII	14	364	14.3	442.8	14.3
VIII	34	176	17.6	300.0	55.9
IX	37	3475	24.3	48.6	218.9
X	27	147	11.1	270.4	56.6
XI	11	227	36.4	54.5	100.0
Mean Rate		1670	21.4	133.8	75.7
NORTHERN SECTOR 1971					
I	23	2083	0	30.4	134.8
II	6	83.3	0	66.7	83.3
III	9	122.2	0	66.7	22.2
IV	16	531.2	18.8	137.5	131.2
V	8	862.5	12.5	62.5	137.5
VI	8	525.0	0	37.5	62.5
Mean Rate		987.1	5.7	67.1	107.1

Catch/100 Net Days

Loc. No.	Days of Effort	Walleye	Maskinonge	L.M. Bass	S.M. Bass	Pumpkinseed	Yellow Perch	Rock Bass	White Sucker	Bullhead	Carp	Total
						SOUTHERN SECTOR 1972						
II	45	211	37.8	15.6	17.8	252	8.9	24.4	93.3	8.9	2.2	673
III	60	70	11.7	105	26.7	6,210	155	1,260	86.7	720	13.3	8,660
V	26	1,560	19.2	84.6	219	2,580	158	142	527	61.5	50.0	5,400
VII	19	174	26.3	100	5.3	9,640	374	1,100	21.0	103	57.9	11,600
XII	28	504	17.8	28.6	46.4	1,570	178	104	323	28.6	53.6	2,860
XIII	29	55.2	10.3	155	13.8	2,320	124	290	155	1,080	10.3	4,210
XIV	42	202	7.1	16.7	35.7	210	61.9	7.1	47.6	19.0	11.9	619
XV	42	143	7.1	7.1	59.5	331	331	45.2	90.5	360	4.8	1,380
XVI	27	141	0	0	22.2	252	74.1	25.9	48.1	0	0	563
XVIIA	16	144	0	6.3	6.5	436	4,850	87.5	31.2	456	0	6,040
XVIIB	16	938	12.5	0	31.2	275	4,075	25.0	188	481	0	6,020
XVIII	15	753	6.7	0	66.7	20.0	0	6.7	313	26.7	67	1,200
Mean Rate		329.3	14.0	47.9	44.1	2,100	523	322	144	303	16.2	3,900
						NORTHERN SECTOR 1972						
III	29	2,679	6.9	306.9	1,317	17,652	817.2	903.4	913.4	451.7	551.7	25,600
IV	28	3,154	46.4	206.7	250.0	13,571	110.7	107.1	564.3	382.1	400.0	18,846
V	48	1,031	2.1	41.7	100.0	656.2	10.4	20.8	56.2	6.2	20.8	1,946
VI	47	363.0	4.2	87.2	114.9	4,247	835.3	57.4	148.9	142.6	6.4	6,028
VIIA+B	26	3,423	19.2	19.2	107.7	4,435	30.8	19.2	211.5	19.2	7.7	8,292
Mean Rate		1,807	12.9	128.1	327.0	6,957	383.7	187.6	323.0	175.8	161.2	10,463

APPENDIX 1C continued

Catch/100 Net Days

Loc. No.	Days of Effort	Walleye	Maskinonge	L.M. Bass	S.M. Bass	Pumpkinseed	Yellow Perch	Rock Bass	White Sucker	Bullhead	Carp	Total
SOUTHERN SECTOR 1973												
III	73	32.9	7.1	27.4	3.2	1,627	72.6	301.4	60.3	457.5	37.0	2,629
VI	15	846.7	13.3	13.3	140.0	340.0	0	0	166.7	46.7	20.0	1,587
VII	73	520	0	41.1	1.4	4,226	156.2	454.8	49.3	379.4	111.0	5,471
IX	69	1,275	53.6	10.1	42.0	473.3	7.2	36.2	88.4	88.4	17.4	2,097
XI	81	85.2	1.2	6.2	9.9	1,512	1,002	517.3	49.4	204.9	32.1	3,421
XIXA	81	698.8	39.5	0	22.2	111.1	27.2	0	328.4	44.4	8.6	1,280
XIXB	81	1,844	6.2	0	109.9	795.1	5,817	35.8	112.3	322.2	1.2	9,044
XX	23	65.2	17.4	0	3.7	339	21.7	26.1	73.9	4.3	8.7	565.2
XXI	14	585.7	7.1	57.1	335.7	2,193	92.8	100.0	64.3	278.6	35.7	3,750
Mean Rate		646.1	16.7	14.1	43.3	1,372	1,164	204.9	115.5	231.8	32.2	3,801
NORTHERN SECTOR												
V	56	2,064	5.4	32.1	114.3	2,730	375.0	71.4	196.4	98.2	28.6	5,716
VI	54	718.5	1.8	222.2	170.4	10,173	2,215	264.8	509.2	290.7	38.9	14,609
VIIA+B	76	915.8	11.8	3.9	46.0	1,056	56.6	21.0	230.3	19.7	3.9	2,366
Mean Rate		1,204	7.0	75.3	102.7	4,203	779.0	107.0	301.1	122.0	21.5	6,929

Catch/100 Net Days

Loc. No.	Days of Effort	Walleye	Maskinonge	L.M. Bass	S.M. Bass	Pumpkinseed	Yellow Perch	Rock Bass	White Sucker	Bullhead	Carp	Total
SOUTHERN SECTOR 1974												
II	47	759.6	14.9	0	134.0	310.6	38.3	57.4	174.5	310.6	25.5	2,326
III	55	23.6	1.8	32.7	5.4	4,165	65.4	430.9	52.7	145.4	7.3	4,931
V	54	479.6	11.1	29.6	98.1	4,918	313.0	537.0	268.5	403.7	77.8	7,137
VIII	54	105.6	11.1	179.6	70.4	3,894	74.1	613.0	105.6	481.5	109.2	5,644
IX	28	925.0	3.6	28.6	332.1	10,246	1,168	1,039	735.7	575.0	85.7	15,139
XI	86	176.7	7.0	24.4	41.9	2,114	225.6	488.4	79.1	358.1	17.4	3,532
XIV	50	2,382	4.0	0	84.0	370.0	8.0	14.0	154.0	194.0	22.0	3,232
XVI	59	3,583	8.5	5.1	139.0	1,764	32.2	133.9	244.1	362.7	40.7	6,314
XIXA	17	164.7	0	0	5.9	229.4	129.4	0	123.5	147.0	5.9	805.9
XIXB	17	1,106	5.9	0	47.0	911.8	82.4	11.8	294.1	800.0	11.8	3,273
XXII	14	71.4	0	278.6	7.1	4,243	128.6	814.3	64.3	771.4	57.1	6,436
XXIII	80	176.2	23.8	31.2	95.0	1,634	41.2	430.0	348.8	371.2	20.0	3,221
XXIV	16	368.8	18.8	6.2	25.0	2,944	237.5	362.5	100.0	181.2	25.0	4,269
Mean Rate		836.7	9.9	39.5	86.6	3,724	161.5	381.3	205.0	401.0	38.5	4,884
NORTHERN SECTOR 1974												
III	89	493.2	1.1	33.7	185.4	1,427	67.4	46.1	158.4	40.4	21.3	2,474
VI	89	424.7	1.1	56.2	42.7	2,782	256.2	92.1	389.9	77.5	40.4	4,163
VIIA+B	12	116.7	0	0	0	233.3	591.7	8.3	108.3	25.0	0	1,083
VIIA+B	144	527.8	0	0.7	76.4	1,170	138.9	13.2	147.2	38.9	6.2	2,119
Mean Rate		476.3	0.6	24.2	93.7	1,634	167.4	42.8	213.5	49.1	19.2	2,721

APPENDIX 1C continued

Catch/100 Net Days

Loc. No.	Days of Effort	Walleye	Maskinonge	L.M. Bass	S.M. Bass	Pumpkinseed	Yellow Perch	Rock Bass	White Sucker	Bullhead	Carp	Total
						SOUTHERN SECTOR 1975						
III	85	41.2	7.0	85.9	14.1	2,276	17.6	235.3	78.8	258.8	7.0	3,022
VIII	73	86.3	21.9	79.4	15.1	1,668	5.5	265.8	93.2	128.8	37.0	2,401
IX	88	694.3	21.6	39.8	265.9	2,686	150.0	197.7	195.0	569.3	108.0	4,908
XI	89	51.7	3.4	10.1	14.6	4,096	276.4	646.1	34.8	110.1	22.5	5,265
XII	67	1,872	6.0	35.8	282.1	3,897	113.4	286.6	126.9	792.5	62.7	7,475
XIV	88	2,312	9.1	14.8	78.4	189.8	5.7	36.4	256.8	176.1	38.6	3,118
XVI	89	1,018	15.7	5.6	112.4	176.4	1.1	14.6	104.5	46.1	140.4	1,635
XXIII	82	102.3	18.2	52.3	87.5	5,269	28.4	1,576	154.5	645.4	21.6	7,956
Mean Rate		755.6	12.9	39.4	105.7	2,509	75.6	414.8	128.9	331.0	55.2	4,428
						NORTHERN SECTOR 1975						
III	88	1,293	2.3	38.6	90.9	1,465	29.5	8.0	215.9	25.0	37.5	3,206
VI	85	334.1	7.0	238.8	104.7	2,997	68.2	75.3	165.9	23.5	311.8	4,324
VIIIA+B	116	1,152	12.9	2.6	154.3	1,684	96.6	13.8	249.1	58.6	10.3	3,434
Mean Rate		954	8.0	83.0	120.4	2,002	67.8	30.1	214.5	38.1	107.3	3,626

APPENDIX 1D: TREATMENT OF MARKED FISH AND POPULATION ESTIMATES. Chemung Lake, Southern Sector, 1971-1975.

Year	Total Catch	Total Clipped	Total Tagged and Clipped	Population Estimate (Fish/ha.) Clip	Tag
			WALLEYE		
1971	5,295	3,671	713	43.6	37.2
1972	1,202	1,001	-	21.5	-
1973	3,295	2,012	-	48.3	-
1974	4,828	4,087	-	36.6	-
1975	5,040	3,295	995	40.8	35.1
			MASKINONGE		
1971	68	14	54	-	1.9
1972	53	15	38	-	0.86
1973	85	-	43	-	0.69
1974	57	-	50	-	0.87
1975	86	-	72	-	-
			LARGE MOUTH BASS		
1971	424	166	223	1.48	1.28
1972	175	59	94	0.12	0.30
1974	228	11	175	0.56	1.16
1975	263	22	197	1.63	1.25
			SMALL MOUTH BASS		
1971	240	149	89	0.90	0.60
1972	161	33	102	0.42	0.97
1973	221	40	179	1.03	5.78
1974	500	80	369	1.55	3.51
1975	705	211	359	2.25	2.23
			PUMPKINSEED		
1972	7,866	7,456			108
1973	6,998	5,168			124
1974	15,175	14,147			91.9
1975	16,734	14,849			173

APPENDIX 1D: TREATMENT OF MARKED FISH AND POPULATION ESTIMATES Cont'd....

Year	Total Catch	Total Clipped	Total Tagged and Clipped	Population Estimate (Fish/ha.)	
				Clip	Tag
			YELLOW PERCH		
1972	1,908	1,367	-	45.7	-
1973	5,736	4,522	-	124	-
1974	923	781	-	4.98	-
1975	504	233	117	3.12	4.48
			ROCK BASS		
1972	1,174	1,104		12.4	
1973	1,045	997		8.61	
1974	2,200	1,993		16.2	
1975	2,767	2,389		19.5	
			WHITE SUCKER		
1972	525	506		12.5	
1973	589	552		9.1	
1974	1,183	1,091		16.5	
1975	860	783		15.4	
			BULLHEAD		
1972	1,106	1,006		11.5	
1973	1,182	1,036		13.6	
1974	2,314	1,179		9.5	
1975	2,208	1,845		7.8	
			CARP		
1972	59	56		0.9	
1973	164		157		8.0
1974	222	6	213		13.6
1975	368	18	332		5.2

APPENDIX 2A: ROTENONE PLOTS. Chemung Lake, Southern Sector. Chronology of Treatments.

Plot No.	Year	Treatment Date	Time of Plot Closure	Plot No.	Year	Treatment Date	Time of Plot Closure
1.	1972	July 5	09:00	7.	1972	July 26	06:00
	1973	July 5	09:00		1973	July 24	06:00
	1974	-	-		1974	-	-
	1975	July 4	09:00		1975	July 24	06:00
2.	1972	July 11	09:00	8.	1972	July 31	06:00
	1973	July 11	09:00		1973	July 26	06:00
	1974	July 11	09:00		1974	July 25	06:00
	1975	July 11	09:00		1975	July 29	06:00
3.	1972	July 18	06:00	9.	1972	Aug. 3	06:00
	1973	July 18	06:00		1973	July 31	06:00
	1974	-	-		1974	-	-
	1975	July 16	06:00		1975	July 31	06:00
4.	1972	July 21	06:00	10.	1972	Aug. 10	09:00
	1973	July 20	06:00		1973	Aug. 10	09:00
	1974	July 19	06:00		1974	Aug. 9	09:00
	1975	July 22	06:00		1975	Aug. 6	09:00
5.	1972	-	-	11.	1972	Aug. 15	09:00
	1973	June 26	09:00		1973	Aug. 15	09:00
	1974	-	-		1974	Aug. 15	09:00
	1975	June 18	09:00		1975	Aug. 15	09:00
6.	1972	June 26	09:00	12.	1972	Aug. 17	09:00
	1973	June 29	09:00		1973	Aug. 17	09:00
	1974	June 28	09:00		1974	-	-
	1975	June 26	09:00		1975	-	-

APPENDIX 2B: ROTENONE PLOTS. Chemung Lake, Southern Sector. Submergent Plant Growth Index.

Plot No.	Plant Growth Index				
	1972	1973	1974	1975	Mean
1.	156	179	-	128	154
2.	142	182	154	188	166
3.	95	91	-	121	102
4.	113	164	148	186	152
5.	-	142	-	143	142
6.	131	168	146	100	136
7.	169	168	-	176	171
8.	91	115	114	70	98
9.	176	195	-	173	181
10.	137	147	168	155	152
11.	176	171	165	195	177
12.	25	29	-	-	27

APPENDIX 2C: ROTENONE PLOTS. Chemung Lake, Southern Sector. Collection of Fish of 20 cm or less.

Plot No.	Mean Plant Growth Index	FISH									
		1972		1973		1974		1975		Mean	
		No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
1.	154	175	441	328	1,058	-	-	549	809	350	769
2.	166	511	1,410	410	1,096	155	632	252	425	332	890
3.	102	87	364	188	884	-	-	149	538	141	595
4.	152	250	750	333	487	261	988	249	609	273	833
5.	142	-	-	320	1,380	-	-	179	685	249	1,032
6.	136	652	999	273	620	78	290	262	267	316	544
7.	171	331	880	391	971	-	-	292	951	338	934
8.	98	135	1,042	486	1,902	133	677	154	1,044	224	1,166
9.	181	350	913	468	1,105	-	-	388	769	402	929
10.	152	378	816	318	1,191	187	857	351	950	308	952
11.	177	362	1,154	353	975	331	1,107	210	765	314	1,000
12.	27	8	17	18	58	-	-	-	-	13	37

APPENDIX 2D. ROTENONE PLOTS. Chemung Lake, Southern Sector. Fish species distribution by plot including all fish taken in plots regardless of size.

Species	Number of Fish 1972	1973	1974	1975	Total	Mean
			PLOT 1			
Yellow Perch	141	156	-	107	404	134.7
Pumpkinseed	12	114	-	83	209	69.7
Rock Bass	3	21	-	2	26	8.7
Largemouth Bass	3	19	-	12	34	11.3
Iowa Darter	3	1	-	6	10	3.3
Bullhead	0	3	-	324	327	109.0
Golden Shiner	0	7	-	0	7	2.3
Blackchin Shiner	0	3	-	0	3	1.0
Brook Stickleback	0	4	-	0	4	1.3
Walleye	0	1	-	0	1	0.3
Spottail Shiner	0	0	-	13	13	4.3
White Sucker	0	0	-	2	2	0.7
Unknown	13	0	-	0	13	4.3
			PLOT 2			
Yellow Perch	125	200	96	47	468	117.0
Pumpkinseed	1	21	11	28	61	15.2
Rock Bass	23	147	21	64	255	63.8
Golden Shiner	38	6	18	0	62	15.5
Spottail Shiner	87	2	1	78	168	42.0
Smallmouth Bass	7	0	0	0	7	1.8
Fantail Darter	2	0	0	0	2	0.5
Largemouth Bass	2	4	1	6	13	3.2
Iowa Darter	3	9	6	9	27	6.8
Bullhead	0	5	0	7	12	3.0
Bluntnose Minnow	0	1	0	0	1	0.2
Carp	0	1	0	1	2	0.5
Blacknose Shiner	0	0	1	0	1	0.2
Unknown	223	17	0	19	259	64.8

APPENDIX 2D continued

Species	Number of Fish 1972	1973	1974	1975	Total	Mean
			PLOT 3			
Yellow Perch	58	72	0	88	218	72.7
Pumpkinseed	1	62	0	48	111	37.0
Rock Bass	7	10	0	5	22	7.3
Smallmouth Bass	2	0	0	1	3	1.0
Fantail Darter	9	0	0	0	9	3.0
Bullhead	2	3	0	1	6	2.6
Largemouth Bass	1	17	0	1	19	6.3
Walleye	0	1	0	0	1	0.3
Iowa Darter	0	0	0	5	5	1.7
Unknown	7	24	0	0	31	10.3
			PLOT 4			
Yellow Perch	73	105	83	99	360	90.0
Pumpkinseed	75	107	109	110	398	99.5
Rock Bass	36	102	16	19	173	43.2
Golden Shiner	6	1	7	1	15	3.8
Smallmouth Bass	3	0	0	0	2	0.8
Fantail Darter	5	0	0	0	5	1.2
Bullhead	1	1	0	0	2	0.5
Largemouth Bass	7	12	30	9	58	14.5
Iowa Darter	2	0	14	1	17	4.2
Brook Stickleback	0	1	0	0	1	0.2
Carp	0	0	1	0	1	0.2
Bluntnose Minnow	0	0	2	0	2	0.5
Spottail Shiner	0	0	0	7	7	1.8
White Sucker	0	0	0	1	1	0.2
Banded Killifish	0	0	0	3	3	0.8
Unknown	43	7	0	1	51	12.8

APPENDIX 2D continued

Species	1972	Number of Fish 1973	1974	1975	Total	Mean
			PLOT 5			
Yellow Perch	-	259	-	64	323	161.5
Pumpkinseed	-	4	-	8	12	6.0
Rockbass	-	26	-	29	55	27.9
Iowa Darter	-	17	-	9	26	13.6
Bluntnose Minnow	-	13	-	0	13	6.5
Blackchin Shiner	-	1	-	0	1	0.5
Spottail Shiner	-	0	-	38	38	19.0
Unknown	-	0	-	31	31	15.5
			PLOT 6			
Yellow Perch	573	202	55	96	926	231.5
Pumpkinseed	2	24	2	148	176	44.0
Rockbass	19	11	14	1	45	11.2
Golden Shiner	1	22	2	0	25	6.2
Carp	3	0	0	0	3	0.8
Bullhead	8	0	0	0	8	2.0
Largemouth Bass	2	12	4	12	30	7.5
Brook Stickleback	4	0	0	0	4	1.0
Central Mudminnow	1	0	0	0	1	0.2
Iowa Darter	0	1	0	2	3	0.8
Blackchin Shiner	0	1	0	0	1	0.2
White Sucker	0	1	1	0	2	0.5
Spottail Shiner	0	0	1	3	4	1.0
Unknown	40	0	0	0	40	10.0

APPENDIX 2D continued

	Number of Fish					
Species	1972	1973	1974	1975	Total	Mean
			PLOT 7			
Yellow Perch	105	171	-	50	326	108.7
Pumpkinseed	52	11	-	28	91	30.3
Rockbass	66	85	-	36	187	62.3
Golden Shiner	69	21	-	1	91	30.3
Fantail Darter	5	0	-	0	5	1.7
Carp	1	4	-	4	9	3.0
Bullhead	2	29	-	102	133	44.3
Largemouth Bass	7	5	-	0	12	3.0
Smallmouth Bass	0	45	-	0	45	15.0
Iowa Darter	0	6	-	9	15	5.0
Spottail Shiner	0	3	-	14	17	5.7
Bluntnose Minnow	0	1	-	49	50	17.7
White Sucker	0	1	-	6	1	0.3
Unknown	25	10	-	0	35	11.7
			PLOT 8			
Yellow Perch	109	176	74	64	423	105.8
Pumpkinseed	16	29	8	35	88	22.0
Rockbass	0	27	28	7	62	15.5
Smallmouth Bass	8	160	2	0	170	42.5
Fantail Darter	1	0	0	0	1	0.2
Mottled Sculpin	1	0	0	0	1	0.2
Bullhead	0	3	1	3	7	1.8
Largemouth Bass	0	5	2	1	8	2.0
Spottail Shiner	0	17	7	11	35	8.8
White Sucker	0	3	1	0	4	1.0
Iowa Darter	0	0	10	20	30	7.5
Slimy Sculpin	0	0	1	0	1	0.2
Bluntnose Minnow	0	0	0	10	10	2.5
Walleye	0	0	0	1	1	0.2
Unknown	25	68	4	2	99	24.8

APPENDIX 2D continued

	Number of Fish					
Species	1972	1973	1974	1975	Total	Mean
PLOT 9						
Yellow Perch	174	236	-	152	562	187.3
Pumpkinseed	80	59	-	83	222	74.0
Rockbass	41	88	-	29	158	52.7
Smallmouth Bass	3	0	-	1	4	1.3
Largemouth Bass	2	6	-	13	21	7.0
Bullhead	0	16	-	10	26	8.7
Golden Shiner	0	40	-	0	40	13.3
Carp	0	5	-	0	5	1.7
White Sucker	0	2	-	0	2	0.7
Bluntnose Minnow	0	0	-	62	62	20.7
Spottail Shiner	0	0	-	7	7	2.3
Iowa Darter	0	0	-	31	31	10.3
Unknown	2	18	-	0	20	6.7
PLOT 10						
Yellow Perch	66	108	50	40	264	66.0
Pumpkinseed	0	57	74	84	215	53.8
Rockbass	230	57	48	65	400	100.0
Golden Shiner	1	6	1	1	9	2.2
Spottail Shiner	16	0	6	33	55	13.8
Smallmouth Bass	6	0	0	1	7	1.8
Fantail Darter	15	0	0	0	15	3.8
Carp	28	9	2	0	39	9.8
Bullhead	6	53	0	60	119	29.8
Largemouth Bass	5	1	5	6	17	4.2
Brook Stickleback	3	0	0	0	3	0.8
Central Mudminnow	1	0	0	0	1	0.2
Iowa Darter	0	1	0	26	27	6.8
Bluntnose Minnow	0	14	2	15	31	7.8
Blackchin Shiner	0	5	0	0	5	1.2
Walleye	0	0	2	0	2	0.5
Unknown	1	2	0	20	23	5.8

APPENDIX 2D continued

Species	1972	Number of Fish 1973	1974	1975	Total	Mean
			PLOT 11			
Yellow Perch	226	211	115	72	624	156.0
Pumpkinseed	47	53	94	44	238	59.5
Rockbass	60	41	60	26	187	46.8
Carp	3	0	0	1	4	1.0
Bullhead	9	2	1	16	28	7.0
Largemouth Bass	1	0	4	2	7	1.8
Iowa Darter	6	29	40	46	121	30.2
Bluntnose Minnow	8	0	16	4	28	7.0
Smallmouth Bass	0	2	0	0	2	0.5
Golden Shiner	0	1	2	0	3	0.8
Spottail Shiner	0	16	1	0	17	4.2
Mottled Sculpin	0	0	1	0	1	0.2
Unknown	2	0	0	0	2	0.5
			PLOT 12			
Smallmouth Bass	5	10	-	-	15	7.5
Fantail Darter	3	0	-	-	3	1.5
Yellow Perch	0	6	-	-	6	3.0
Pumpkinseed	0	1	-	-	1	0.5
Mottled Sculpin	0	1	-	-	1	0.5
Unknown	0	0	-	-	0	0

APPENDIX 2E: TOTAL FISH COLLECTION AND ANNUAL CATCH RATE PER PLOT.

Species	1972 11 Plots		1973 12 Plots		1974 6 Plots		1975 11 Plots		Total 40 Plots	Mean Rate
	Total No.	Rate	Total No.	Rate	Total No.	Rate	Total No.	Rate	No.	
Yellow Perch	1,650	150	1,902	158	473	79	879	80	4,904	122
Pumpkinseed	286	26	342	28	298	50	699	63	1,625	41
Rock Bass	485	44	437	36	187	31	283	26	1,392	35
Bullhead	28	2	115	10	2	0	523	48	668	17
Spottail Shiner	103	9	38	3	16	3	204	18	361	9
Iowa Darter	14	1	64	5	70	12	164	15	312	8
Smallmouth Bass	34	3	217	18	2	0	3	0	256	6
Golden Shiner	115	10	104	9	30	5	3	0	252	6
Largemouth Bass	30	3	81	7	46	8	62	6	219	6
Bluntnose Minnow	8	1	29	2	20	3	140	13	197	5
Carp	35	3	19	2	3	1	6	1	63	2
Fantail Darter	40	4	0	0	0	0	0	0	40	1
Brook Stickleback	7	1	5	0	0	0	0	0	12	0
White Sucker	0	0	7	1	2	0	3	0	12	0
Blackchin Shiner	0	0	10	1	0	0	0	0	10	0
Walleye	0	0	2	0	2	0	1	0	5	0
Banded Killifish	0	0	0	0	0	0	3	0	3	0
Mottled Sculpin	1	0	1	0	1	0	0	0	3	0
Central Mudminnow	2	0	0	0	0	0	0	0	2	0
Blacknose Shiner	0	0	0	0	1	0	0	0	1	0
Slimy Sculpin	0	0	0	0	1	0	0	0	1	0
Unknown	331	35	146	12	4	1	73	7	604	15

APPENDIX 3A: FISH SAMPLES TAKEN FROM AQUATIC PLANTS CUTS AND HARVESTED IN CHEMUNG LAKE. Southern Sector, 1974 and 1975.

Year	Species	Number	Mean No. per sample	Mean Length (mm)	Length Range (mm)	Estimated Mean Fish Weight (g)	Estimated Mean Weight per Sample (g)	Wet Weight (Plants:Fish)
1974[1] June 19 - Oct. 31	Yellow Perch	105	1.4	57	12-141	3.6	5.15	
	Pumpkinseed	54	0.7	61	22-131	4.4	3.21	
	Rock Bass	14	0.2	67	25-154	9.5	1.80	
	Other[3]	4	0.1	-	-	-	0.08	
	Total	177	2.4	-	-	-	10.24	1000:0.98
1975[2] July 2 - Oct. 24	Yellow Perch	260	2.0	59	20-190	3.9	7.8	
	Pumkinseed	161	1.3	45	16-116	1.6	2.1	
	Rock Bass	37	0.3	46	24-134	3.3	1.0	
	Other[4]	18	0.1	-	-	-	0.1	
	Total	476	3.7	-	-	-	11.0	1000:1.06

[1] No. Plant Samples = 74, Total Wet Weight = 780 kg., Mean Sample Wet Weight = 10.5 kg., Range in Sample Wet Weight = 4.9-14.2 kg.

[2] No. Plant Samples = 128, Total Wet Weight = 1,327 kg., Mean Sample Wet Weight = 10.4 kg., Range in Sample Wet Weight = 5.4-26.2 kg.

[3] Largemouth Bass (1), Carp (1), Iowa Darter (1), Emerald Shiner(1).

[4] Largemouth Bass (6), Bullhead (1), Iowa Darter (1), Bluntnose Minnows (5), Shiners (5).

APPENDIX 3B: AQUATIC PLANT HARVESTING IN CHEMUNG LAKE. Southern Sector, 1973 to 1975, from the Ontario Ministry of the Environment.

Year	Harvesting Dates	Area Cut		Wet Weight of Plants Removed		Peak Biomass			Harvest as a % of Peak Biomass
		(Acres)	(Ha.)	(Tons)	(kg)	Tons	Kg	Kg/Ha.**	
1973	August 15-October 31	656*	266	1,268	1.15×10^6	17.8×10^3	16.2×10^6	20.3×10^3	7.1
1974	June 17 -October 31	646	262	2,131	1.93×10^6	18.8×10^3	17.1×10^6	21.4×10^3	11.3
1975	June 24 -October 31	734	297	3,325	3.02×10^6	17.8×10^3	16.1×10^6	20.2×10^3	18.7

*In 1973 only 250 acres of plants were actually cut and harvested. That year saw a massive upwelling of plants from the bottom so that they were floating and harvesters merely picked them up from the surface. Acreage equivalents for these floating plants were estimated by using two loads of floating vegetation as equal to one acre. Examination of six samples of harvested floating plants indicated no loss of fish from this source.

**Based on an area of 800 ha. south of the Bridgenorth Causeway.

APPENDIX 4A: CHEMUNG LAKE CREEL CENSUS, 1971 to 1976

Year	Anglers Contacted	Hours Fished	Catch of Fish Creeled								
			Walleye	Maskinonge	L.M. Bass	S.M. Bass	Yellow Perch	Pumpkinseed	Rock Bass	Bullhead	TOTAL
						NORTHERN SECTOR					
1971	443	853	127	0	8	4	69	8	13	9	238
1972	1,141	1,493	151	1	7	12	74	108	2	2	357
1973	2,037	2,462	210	8	15	32	102	30	7	0	404
1974	1,795	2,325	190	5	8	31	193	108	12	12	559
1975	614	831	50	6	1	8	15	20	1	0	101
1976	294	350	23	2	2	3	0	0	0	0	30
Total	6,326	8,319	751	22	41	90	453	274	35	23	1,689
Mean	1,054	1,386	125	4	7	15	75	46	7	4	282
						SOUTHERN SECTOR					
1971	646	909	201	2	3	4	23	4	2	1	240
1972	1,047	1,338	149	2	0	3	89	18	2	2	265
1973	1,408	1,686	257	3	6	21	194	49	18	5	547
1974	1,036	1,297	238	1	2	7	71	33	21	23	396
1975	592	857	100	2	1	10	5	0	3	1	122
1976	229	278	76	0	1	0	2	0	0	0	79
Total	4,958	6,359	1,015	10	13	45	384	104	46	32	1,649
Mean	826	1,060	169	2	2	8	64	17	8	5	275

APPENDIX 4B: ESTIMATED ANGLER EFFORT AND CATCH STATISTICS

Year	Angler hours/ ha./100 days		Total Fish Harvest/ha./100 days		Total Weight kg./ha./100 days		C.U.E. Fish/Angler hr.		Mean Trip Length (Hours)	
	North	South	North	South	North	South	North	South	North	South
1971	1.3	33.2	4.8	7.1	2.2	3.4	0.3	0.3	3.8	2.8
1972	25.9	35.7	7.1	7.1	2.8	2.7	0.2	0.2	2.6	2.6
1973	22.9	27.8	3.9	9.1	1.7	2.9	0.2	0.3	2.4	2.3
1974	21.4	29.4	5.1	9.0	1.5	3.3	0.2	0.3	2.6	2.5
1975	17.4	21.0	1.9	4.3	0.9	2.7	0.1	0.1	2.7	2.9
1976	10.5	16.4	0.8	4.5	0.4	2.2	0.1	0.3	2.4	2.4
Mean	19.2	27.9	3.9	6.9	1.6	2.8	0.2	0.3	2.6	2.6

APPENDIX 4C: ESTIMATED ANNUAL HARVEST BY SPECIES, CHEMUNG LAKE CREEL CENSUS, 1971 to 1976.

Year	Number and Weight (kg.)/ha./100 days															
	Walleye		Maskinonge		L.M. Bass		S.M. Bass		Yellow Perch		Pumpkinseed		Rock Bass		Bullhead	
									NORTHERN SECTOR (1480 ha.)							
1971	2.59	1.70	-	-	0.17	0.13	0.12	0.06	1.30	0.13	0.17	0.02	0.26	0.03	0.18	0.08
1972	2.74	2.05	0.01	0.02	0.19	0.15	0.24	0.13	1.50	0.16	2.25	0.23	0.06	0.01	0.06	0.02
1973	1.96	1.11	0.08	0.14	0.15	0.14	0.32	0.19	0.98	0.08	0.30	0.03	0.07	0.01	-	-
1974	1.71	0.89	0.04	0.11	0.07	0.03	0.22	0.16	1.73	0.17	1.02	0.09	0.11	0.02	0.11	0.04
1975	0.97	0.41	0.12	0.30	0.02	0.01	0.19	0.13	0.26	0.02	0.32	0.03	0.02	0.0	-	-
1976	0.63	0.28	0.04	0.12	0.04	0.01	0.06	0.02	-	-	-	-	-	-	-	-
									SOUTHERN SECTOR (800 ha.)							
1971	4.42	2.91	0.06	0.12	0.06	0.05	0.08	0.04	2.18	0.21	0.73	0.01	0.08	0.01	0.05	0.02
1972	4.13	2.20	0.08	0.15	-	-	0.12	0.05	2.22	0.19	4.42	0.05	0.03	0.01	0.07	0.03
1973	4.18	1.93	0.05	0.13	0.10	0.09	0.33	0.26	3.23	0.28	0.86	0.01	0.31	0.06	0.09	0.02
1974	5.44	2.65	0.02	0.06	0.05	0.02	0.17	0.08	1.60	0.14	0.73	0.07	0.46	0.08	0.55	0.14
1975	3.50	1.96	0.03	0.58	0.03	0.01	0.34	0.13	0.17	0.02	-	-	0.13	0.03	0.04	0.01
1976	4.34	2.18	-	-	0.05	0.01	-	-	0.10	0.01	-	-	-	-	-	-

APPENDIX 4D: CHEMUNG LAKE CREEL CENSUS ANGLER PREFERENCE BY SPECIES

Year	Percentage of Anglers Fishing for Each Species					
	Walleye	Maskinonge	Bass	Pumpkinseed	Yellow Perch	Bullhead
			NORTHERN SECTOR			
1971	100	0	0	0	0	0
1972	93.2	2.3	4.5	0	0	0
1973	90.1	4.3	4.9	0	0.7	0
1974	92.6	2.0	4.4	0	0.9	0
1975	91.4	2.6	4.6	0.5	1.0	0
1976	90.1	2.7	7.1	0	0	0
			SOUTHERN SECTOR			
1971	96.0	0.4	1.9	0	0.9	0
1972	96.1	2.2	1.6	0	0	0
1973	92.8	2.2	3.6	0	1.3	0
1974	93.8	1.2	2.3	0.3	1.6	0.8
1975	96.8	1.0	0.8	0	1.4	0
1976	99.6	0	0.4	0	0	0

CHAPTER 9

PUBLIC OPINION OF THE HARVESTING PROGRAM AND RECREATIONAL QUALITY OF THE LAKE

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INTRODUCTION

In 1975, staff of the Ministry of the Environment interviewed residents of Southern Chemung Lake in an attempt to define major recreational uses of the lake and assess public opinion of water quality and the aquatic plant harvesting program. A sample format used for the interviews has been provided in Appendix I. The results are expressed as a percentage of the number of respondents. However, since several questions allowed for the selection of more than one category by the respondent, in some instances the summed percentages exceed 100%.

Southern Chemung Lake has 523 residences that border directly on the lake and an additional 200, one to four lots back from the shoreline. Although an all out effort was made to include all residences bordering on the lake, several were excluded due to owner absenteeism or double ownership. A total of 438 residents were interviewed of which 352 were located directly on the lakeshore. Two hundred and fifty of the residences were classified as permanent homes, 54 cottages were used periodically throughout the year and 134 were summer cottages.

The development of Chemung Lake was obviously fairly intense several years ago since 66% of the residences were more than 10 years old. More recent development within the last five years primarily includes permanent homes situated several lots back from the lake perimeter.

RESULTS

Major Recreational uses of the lake and public opinion of recreational quality. Local residents selection of this area for their homes or cottages was highly influenced by their desire to be near the water for aesthetic and recreational purposes and a desire to get away from city life. The lake is thus of prime importance and concern to all the people interviewed. More than 55% of the respondents indicated that they had observed noticeable changes in water quality during the last five years, and most of the people interviewed felt that the present recreational quality was in jeopardy. The most quoted problems were increasing weed growth, shoreline accumulations of weeds and increasing algal growths in the lake. These problems resulted in the inability of boaters to move away from their docks, unattractive beach areas and an overall reduction in aesthetic values. Other problems of concern to the residents included odours from decaying vegetation, too much development around the lake, noise levels, suds, foam, oil and gas on the water surface, decreasing wildlife abundance and changes in water levels.

Despite these problems, 45% of the respondents still rated the lake as excellent or good for recreational purposes. An additional 25% rated the lake as fair, while 30% felt the recreational quality was poor to very poor. Most of the residents interviewed expressed a desire to maintain the lake "as is" or hopefully improve its present quality.

Residents rating of lake for recreational quality

Excellent	12%
Good	33%
Fair	25%
Poor	16%
Very Poor	14%

Major problems causing a deterioration in recreational quality

Increased weed growth in lakes	86%
Shoreline accumulations of weeds	63%
Increased algal growth	27%
Odours	13%
Water Turbidity	11%
Littering	9%
Increased numbers of cottages	7%
General noise level	7%
Suds or foam on water	6%
Water level variations	6%
Motorboat oil and gas on water	4%
Decreasing wildlife abundance	3%
Motorboat noise level	3%

Many of the residents interviewed expressed opinions on additional problems and made suggestions for changes or improvements. Probably the most frequently requested improvement (particularly by residents not living directly on the lakeshore) was for better public access, more launching facilities and clean public swimming areas. Numerous residents suggested regulations on the use of power boats, safer water skiing practises, noise regulations for snowmobiles and stricter hunting laws. Several advocated extensive use of chemicals to kill off all the vegetation and subsequent restocking of the lake with fish. Others believed size limits for fish should be strictly enforced to protect the fisheries. Many residents complained about the stumps and logs in the lake and felt that they should be removed and the shallow areas dredged. Finally, most residents expressed concern about malfunctioning septic tanks and over-use of trailer camp facilities and felt that inspections should be stepped up to eliminate any potential damage to the water quality.

As expected, the major recreational uses of the lake were swimming, boating and fishing.

Recreational uses of the lake
(based on respondents ranking in order of importance)

Boating	33%
Swimming	32%
Fishing	15%
Aesthetics	10%
Water skiing	7%
Snowmobiling	7%

The intense use of the lake for recreation is further exemplified by the fact that 87% of the respondents owned at least one boat and several owned two or three boats. At least 76% owned an outboard motor boat.

Types of boats owned by respondents

Outboard	76%
Canoe	32%
Sailboat	12%
Rowboat	10%
Cabin Cruiser	5%

Fishing activities were engaged in by 68% of the respondents. Of these, 46% felt that fishing success had declined in the last five years due to overfishing and weed growth.

Fishing conditions in Chemung Lake

Improved	8%
Same	29%
Declined	46%
Don't know	17%

A total of 330,600 man-days were spent at the residences on the lake; 58,600 at cottages and 272,000 at permanent homes. The numbers of man-days spent on each major recreational activity are tabulated below.

Activity	1-5 days	Number of man-days 6-10 days	more than 10
Swimming	442	85	1013
Power boating	97	93	728
Fishing	159	120	436
Water Skiing	79	99	371
Snowmobiling	50	58	349
Canoeing	65	48	266
Sailing	24	9	98
Hiking	19	37	70
Snowskiing	22	25	68
Nature Study	21	20	54
Skating	9	23	42
Hunting	22	8	30

Public opinion of the experimental aquatic plant harvesting program. Residents opinions regarding the usefulness and success of the harvesting program were extremely varied. Forty eight percent felt that harvesting had an overall beneficial effect on the lake. Their primary reasons for this opinion included retardation of growth or reduced growth during the following year (particularly along the east and west shorelines of the lake), immediate use of harvesting areas for boating, swimming and fishing and the removal of plant biomass from the lake. Many also felt that harvesting had curtailed weed growth in Southern Chemung Lake as compared to other lakes on the system such as Buckhorn Lake.

Some 23% of the residents felt that harvesting had made no difference to the lake, although in many cases they were referring to their own immediate areas of the lake which had not been harvested.

The strongest opinions were expressed by the 19% who felt that harvesting had not benefited the lake. Most of this group felt that harvesting accelerated plant growth and resulted in denser weed beds. Many also indicated that they were opposed to the program because their own immediate areas of the lake were not harvested. This response was particularly evident among residents in the extreme southern portion of the lake where tree stumps, logs and extremely shallow water depths precluded the safe operation of the machinery. The biased nature of the responses is further illustrated when Figure 1 is compared to the maps of the harvested area provided in Chapter 1. The single major complaint relating to the harvesting operation was the shoreline accumulation of floating weeds which had escaped from the machines, with 34% of the people interviewed expressing this concern.

Public opinion of harvesting program

Benefited the lake	48%
Made no difference	23%
Not benefited lake	19%
No opinion	10%

Why harvesting has benefited the lake

Reduced weed growth	17%
Immediate use of cut areas	16%
Biomass removal	6%
Improved boating	6%
Fewer floating weeds	3%
Improved fishing	3%
Weed growth better than other lakes	2%

Why harvesting has not benefited the lake

Increased weed growth	10%
Spreading of weed growth	3%
Rapid regrowth of weeds	3%
My area not cut	2%
Roots of plants not removed	1%
Program not extensive enough	1%

In response to enquiries concerning the future of the program, a surprising 85% of the total number of residents interviewed indicated that harvesting should be continued, an additional 5% were undecided and 10% opposed.

Should the harvesting program be continued?

Yes - 85%
No - 10%
Undecided - 5%

Of the 85% favouring a continuation of the harvesting operation, 27% felt that the program should be continued if proven beneficial by the research studies, 20% favoured continuation to assess the long range impact and an additional 11% felt that harvesting definitely reduced weed growth in the lake.

Reasons for favouring a continuation of the harvesting program	
If proven beneficial	27%
To assess future impact	20%
Reduces weed growth	11%
"Anything helps"	9%
Immediate use of cut areas	7%
Improved boating	6%
Biomass removal	3%
Improved fishing	1%
Removal of floating vegetation	1%

The major reasons expressed by the 10% of the residents opposed to the continuation of the program are as follows:

No visible difference to lake - 4%
Weed growth denser - 3%
Regrowth too rapid - 1%

Funding of the harvesting operation

To assess public opinion on "who should pay" for the harvesting program, the residents were provided with several alternatives ranging from government to private sources. Because of heavy non-resident usage of the lake, many of the respondents favoured a division of the funding among the various government agencies and local residents. Others favoured funding by the provincial government to preserve the tourist trade or by the federal government since the lake is part of a navigable waterway. Only 12% of those interviewed felt that harvesting should be funded solely by the local residents through special taxation since they derived the most benefit from the program in terms of recreational potential and improved property values. Several residents within this group, however, felt that they were already overtaxed and indicated that a portion of their existent municipal taxes should be channelled into weed harvesting.

Additional opinions relating to the funding of the harvesting program included the use of monies generated from boating, fishing and snowmobile licences, federal tax money from docking licences, gasoline and lockage fees and increased taxation of marinas and resort operators. Other residents, particularly those with residences adjacent to areas inaccessible to the harvesters felt that they were under no obligation to contribute to a harvesting program that did not benefit them personally. Several expressed the opinion that each maintain their immediate shoreline by using sand, plastic or chemicals and the remainder of the lake left to the expense of some other agency.

Who should fund the harvesting program

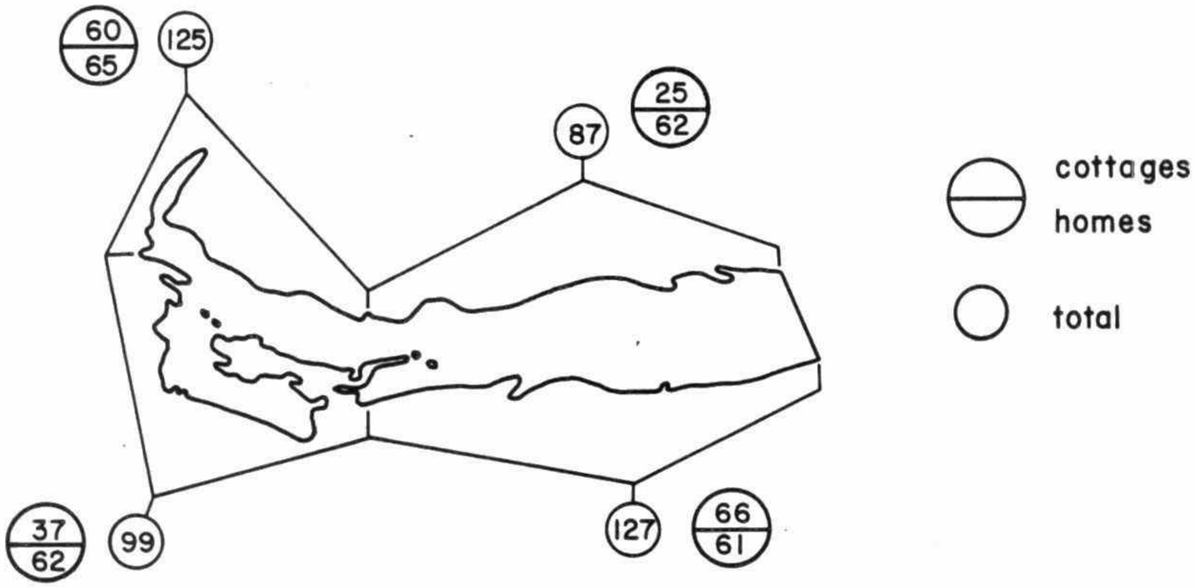
Provincial government	68%
Federal government	40%
Municipal government	15%
Special taxation of local residents	18%
Voluntary contributions	11%

Some of the major reasons expressed by the residents for their proposed funding suggestions are as follows:

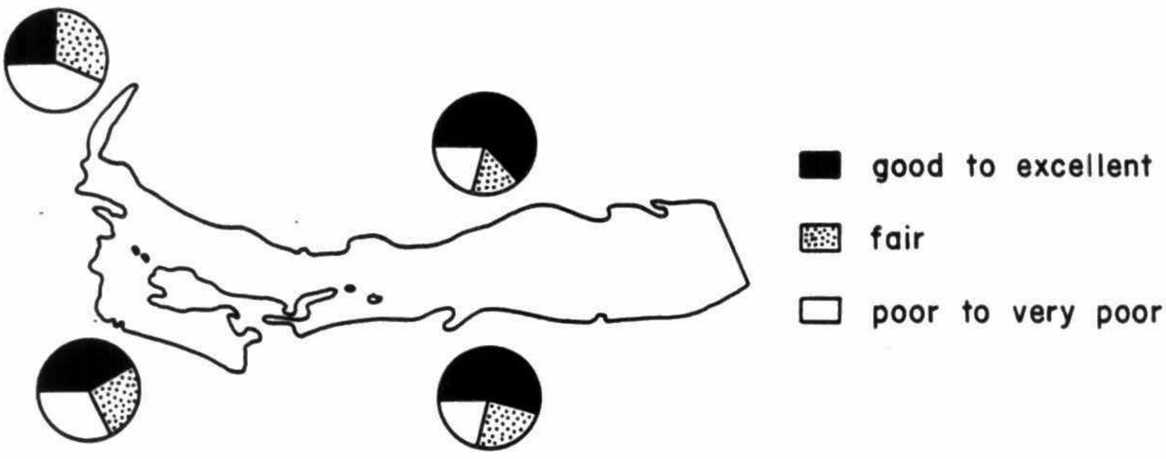
Everyone who uses lake should pay	22%
Lake is provincial government responsibility	17%
Promote tourism	16%
Lake is part of federal waterway	12%
Residents benefit the most	11%
Residents already overtaxed	11%
Non-residents use lake	10%
Federal government collects taxes	5%
Too big an expenditure for municipality	2%

Of the total number of residents interviewed, 222 or 51% indicated that they would be prepared to contribute to a beneficial harvesting program on an annual basis.

Cottage and Home Distribution



Residents Opinion of Lake's Recreational Quality



Residents Opinion of Harvesting

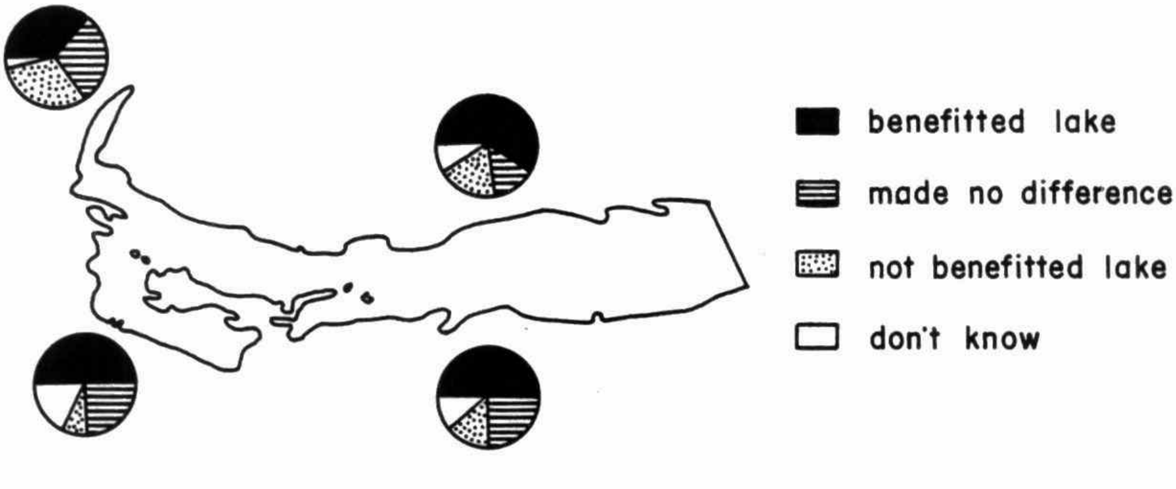


FIG. 1. Relationship between public opinion about harvesting and residence location on lower Chemung Lake.

APPENDIX

QUESTIONNAIRE

1. *What is your correct address:*

*Township*______________________________

*Conc*______________________________

*Lot*______________________________

2. *Is this a permanent residence*______________

*If a permanent residence, how many people reside in it year round?*______________

3. *Approximately how old is the cottage (or residence).*

______ *1-5 years*
______ *6-10 years*
______ *Over 10 years*

4. *How long have you owned this cottage (or residence).*

______ *Less than 6 months*
______ *6 months - 2 years*
______ *2-5 years*
______ *5-10 years*
______ *Over 10 years*

5. *If a cottage, do you use, or intend to use it during the winter?*

______ *Yes*
______ *No*

6. *Are you a member of a cottager's or tourist association?*

______ *No*
______*Yes, please specify*______________

7. *How large is your property?*

______________*feet by* ______________*feet:*

or

______________*acres.*

8. *Where is your lot situated? (please answer both A and B).*

A.	______ *on mainland*	______ *on an island*
B.	______ *on the lakeshore*	______ *three lots back*
	______ *one lot back*	______ *four lots back*
	______ *two lots back*	______ *more than four lots back*

9. *If situated on lakeshore, what is the length of the water frontage?*

______________*ft.*

10. *For each of the four seasons last year (1974), please estimate (i) the approximate number of days your cottage was used during each of the seasons, and (ii) the average number of people that used the cottage during each season.*

	Number of days/season	*Average Number of people/season*
Winter.................	______	______
Spring.................	______	______
Summer.................	______	______
Fall...................	______	______

11. *Please indicate with a check mark when your cottage is used during the seasons that apply.*

	Weekends	*During the Week*	*Family Vacations*
Spring.................	____	____	____
Summer.................	____	____	____
Fall...................	____	____	____
Winter.................	____	____	____

12. *For what reason(s) did you purchase your cottage or home at this location?*

____

____

____

____

____

13. *How would you rate the lake nearest your dwelling for recreational purposes?*

Excellent	*Good*	*Fair*	*Poor*	*Very Poor*
____	____	____	____	____

14. *Have you noticed any change in the quality of your lake in the past five years?*

Yes	*No*	*Don't know*
____	____	________

15. For each of the following, please indicate with a check whether you consider it a problem and also if there has been an increase, decrease, or if it has remained the same during the time you have owned your cottage or home.

	Check if it is a problem	Increase	Decrease	Same
Algae growth............	____	____	____	____
Water colouring.........	____	____	____	____
Water level variations..	____	____	____	____
Weeds in lake...........	____	____	____	____
Water weeds washing ashore.................	____	____	____	____
Odours..................	____	____	____	____
Motorboat oil and gas...	____	____	____	____
Wildlife abundance......	____	____	____	____
Number of cottages......	____	____	____	____
Littering...............	____	____	____	____
Suds or foam............	____	____	____	____
General noise level.....	____	____	____	____
Boat noise only.........	____	____	____	____
Other, specify..........	____	____	____	____
______________________				

16. What are your most important recreation uses of your lake? Please rank according to order of importance

a) ______________________________

b) ______________________________

c) ______________________________

17. It is important that information be obtained on selected recreational activities over the past 12 months at your lake. For the activities listed below, please

a) Check the appropriate box for the approximate number of days people participated in each activity.

b) Estimate the average number of people who would participate in each activity on the average day.

Activity	*a) Number of Days*			*b) Average Number of people*
	1-5	*6-10*	*More than 10*	
Swimming............	___	___	___	___
Fishing.............	___	___	___	___
Skin & Scuba Diving.	___	___	___	___
Water skiing........	___	___	___	___
Sailing.............	___	___	___	___
Canoeing............	___	___	___	___
Power Boating (not including fishing & water skiing).....	___	___	___	___
Hiking..............	___	___	___	___
Horseback Riding....	___	___	___	___
Nature Study........	___	___	___	___
Hunting.............	___	___	___	___
Snowmobiling........	___	___	___	___
Snowskiing..........	___	___	___	___
Other, specify				
___	___	___	___	___
___	___	___	___	___

18. a) Do you like to fish? Yes _____ No _____
If yes, please anser 18 b) and c).

b) Would you say that fishing conditions have i) improved _____ ii) declined _____ iii) remained the same _____ in the time you have fished the lake nearest your cottage.

c) In the lake nearest your cottage, what type of fish do you i) usually catch ii) prefer to catch. (Check as many as apply).

	(i) Usually Catch	(ii) Prefer to Catch
Bass........................	______	______
Carp........................	______	______
Catfish.....................	______	______
Muskellunge.................	______	______
Northern pike...............	______	______
Perch.......................	______	______
Yellow pickerel.............	______	______
Panfish (bluegills, sunfish, etc.)...............	______	______
Other, specify ______________________	______	______

19. a) Do you own, rent, or borrow any kind of boat(s) at your cottage?

Yes ______ No ______

b) If yes, please list the number and kind of boats that you use, (own, rent or borrow) at your cottage.

Canoe..............................	______
Sailboat...........................	______
Row boat...........................	______
Outboard Motor Boat................	______
Cabin cruiser (includes all inboards)..	______
Other specify:	
______________________	______
______________________	______

20. If you own, rent or borrow an outboard motor, what size (horsepower) is it? If you have more than one, please list the horsepower of each one.

Horsepower: 1. ________ 2. ________ 3. ________

21. What is your impression of the Ministry of the Environment experimental weed harvesting programme? Has it

a) Benefited the lake __________ Why ____________________

b) Not benefited the lake __________ Why ____________________

c) Made no difference __________ Why ____________________

22. What in your opinion are the problems created by the weed harvesting operation. (Check as many as you want).

a) Shoreline accumulations of weeds. __________

b) Faster growth of plants following cutting. __________

c) Noise from machinery. __________

d) Inconvenience due to equipment operating on lake. __________

e) Other, specify. __________

f) None. __________

23. Are you in favour of a continuing harvesting programme on your lake?

Yes __________ Why ____________________

No __________ Why ____________________

24. How should a weed harvesting programme be funded?

a) Federal government. __________

b) Provincial government __________

c) Municipal Government __________

d) Special taxes levied against local residents. __________

e) Voluntary contributions by residents. __________

f) Other, specify. ____________________ __________

25. Why do you feel that a harvesting programme should be funded in this manner. Explain.

____

____

____

____

____

26. How much would you be personally prepared to contribute on an annual basis towards a continuing weed harvesting programme on your lake assuming research proved it to be beneficial.

____

27. *What recommendations would you make to improve recreational qualities of the lake.*

____

____

____

____

____

____

28. *What is (a) the source of your drinking water and (b) what treatment do you provide for your drinking water?*

a) Source	*b) Treatment*
________ *Direct from the lake*	________ *Filtration Unit*
________ *Well*	________ *Chlorination*
________ *Spring*	________ *Boiling*
________ *Other, specify*	________ *None*
______________________________	________ *Other, specify*
	______________________________

29. *For each of the 3 kinds of wastes listed below, check the box which best describes the method of disposal used at your dwelling. (Check only one method of disposal for each kind of waste).*

	a) Toilet Wastes	*b) Sink and Bath Wastes*	*c) Laundry Wastes*
No waste of this type....	______	______	______
Septic tank with tile field...................	______	______	______
Pit privy................	______	______	______
Combustion unit..........	______	______	______
Holding tank (no discharge)	______	______	______
Seepage pit..............	______	______	______
On to ground.............	______	______	______
Don't know...............	______	______	______
Other, specify...........			
________________________	______	______	______

30. (a) *Do you plan to alter or replace facilities for disposal of any of the wastes?*

	i) Toilet Wastes	*ii) Sink and Bath Wastes*	*iii) Laundry Wastes*
Yes..................	______	______	______
No...................	______	______	______
Don't know...........	______	______	______

(b) *If "yes", what type of disposal will you change to?*

	i) Toilet Wastes	*ii) Sink and Bath Wastes*	*iii) Laundry Wastes*
Septic tank with tile field...............	______	______	______
Pit privy............	______	______	______
Combustion unit......	______	______	______
Holding tank (no discharge).......	______	______	______
Seepage pit..........	______	______	______
On to ground.........	______	______	______
Other, specify....... ____________________	______	______	______

31. *Where do you do most of your laundry when at your cottage?*

a) ______ *at cottage*

b) ______ *at local laundromat*

c) ______ *both of the above (a and b)*

d) ______ *at permanent residence.*

e) ______ *other, please specify*

____

32. *Check off one or more boxes which best describe your laundry soap and/or detergent use while at your cottage.*

______ *use several brands of detergent*

______ *use one particular brand regularly. Specify*____________

______ *use a no phosphate detergent. Specify*____________

______ *use a laundry soap. Specify*____________

33. *Which of the following items do you presently use at your cottage (or home).*

_____ *automatic clothes washer* _____ *wringer washer*

_____ *automatic dishwasher* _____ *none of the above*

34. *Which, if any, do you plan to purchase for use in your cottage (or home).*

_____ *automatic clothes washer* _____ *wringer washer*

_____ *automatic dishwasher* _____ *none of the above*

_____ *don't know*

35. *Did you use lawn and garden fertilizers on your property in 1974?*

_____ *Yes* _____ *No*

If "yes", what product and how many pounds?

_______________ *pounds of* _______________ *plus*

_______________ *pounds of* _______________.

36. *Are there any additional comments that you would like to make?*

____

____

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